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U.S. Army Environmental Center

Terrestrial Ecological Risk Assessment Army Materials Technology Laboratory

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August 1995

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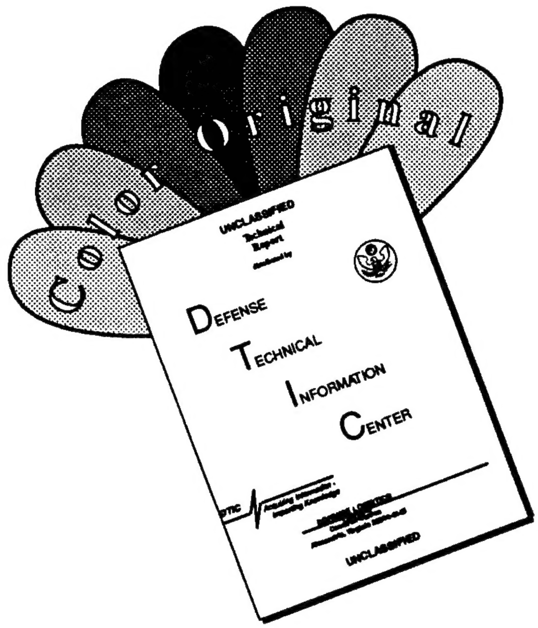

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TERRESTRIAL ECOLOGICAL RISK ASSESSMENT

ARMY MATERIALS TECHNOLOGY LABORATORY

FINAL

Document # SSIM-AEC-BC-CR-95071

Prepared for:

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Maryland 21010-5401

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August 1995

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TERRESTRIAL ECOLOGICAL RISK ASSESSMENT

1.0 INTRODUCTION

The objectives of this ecological risk assessment are to identify and estimate the potential terrestrial ecological impacts associated with the chemicals of potential concern detected in soils at the U.S. Army Materials Technology Laboratory (AMTL) Site in Watertown, Massachusetts. The assessment focuses on the potential for exposure and impact to terrestrial fauna that inhabit or are potential inhabitants of the site. The location of the site and surrounding vicinity is shown in Figure 1-1.

The technical guidance for performance of the ecological risk assessment comes primarily from the following sources: *Ecological Risk Assessment* (EPA, 1986), *Ecological Assessment of Hazardous Waste Sites: A Field and Laboratory Reference* (EPA, 1989a), *Risk Assessment Guidance for Superfund — Volume II, Environmental Evaluation Manual* (EPA, 1989b), *Summary Report on Issues in Ecological Risk Assessment* (EPA, 1991a), *Guidance for Disposal Site Risk Characterization in Support of the Massachusetts Contingency Plan* (MDEP, 1994), *Framework for Ecological Risk Assessment* (EPA, 1992a), and *Wildlife Exposure Factors Handbook* (EPA, 1993). Numerous other information sources were used to assist in this report preparation and are included in the references section.

The subsections that follow provide the objectives, approach, and results of the evaluation of potential ecological impacts associated with chemicals of potential concern at the AMTL Site.

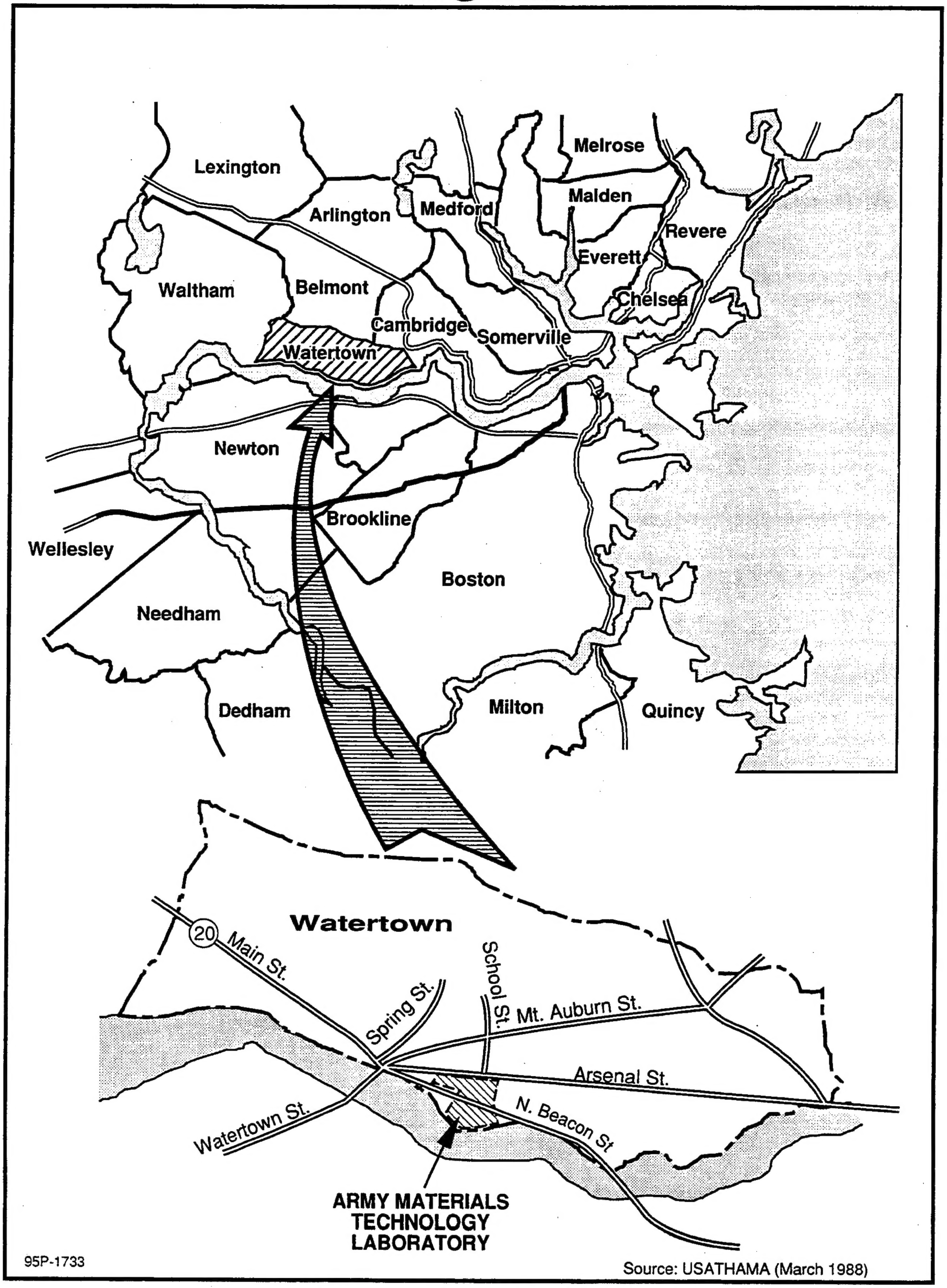


FIGURE 1-1 SITE LOCATION MAP

2.0 DATA EVALUATION AND REDUCTION

2.1 Approach

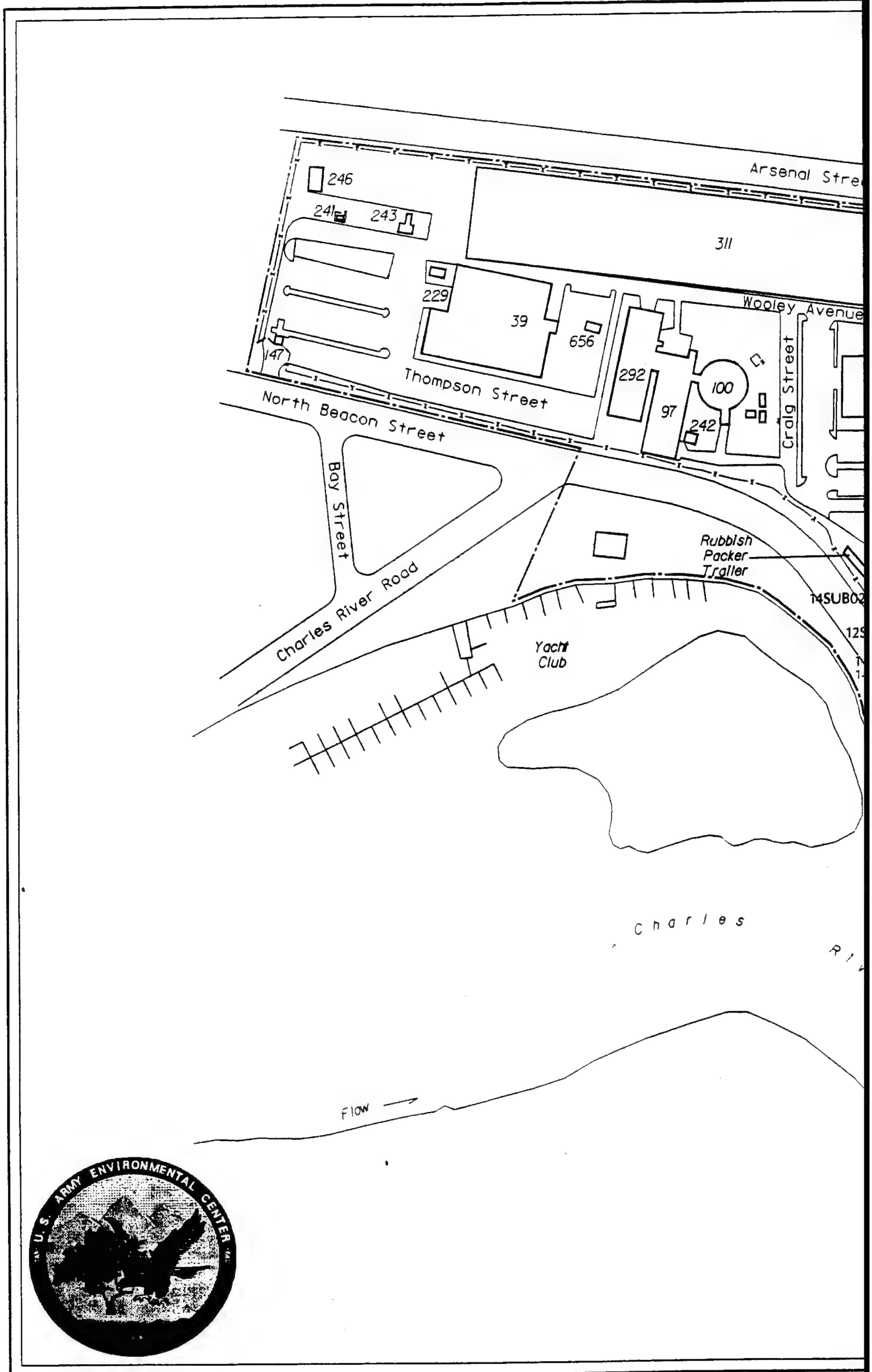
The objectives of the data evaluation and reduction are to review and summarize the analytical data for soils, and to select the chemicals of potential concern to be evaluated in the ecological risk assessment. The soils data used in this assessment were collected from a 0-2 foot interval during the Phase I (WESTON, 1991) and Phase II (WESTON, 1994) remedial investigations at the site, and represent 36 locations in the park and in the open space area in the vicinity of the Commander's Quarters. The soil sampling locations are shown in Figure 2-1. Soils data from the 0 to 2 foot interval were used, since these are the soils that ecological receptors are most likely to come into contact with.

The chemicals analyzed in soils included volatile organic compounds (VOCs), semivolatile organic compounds (SVOCs), pesticides/polychlorinated biphenyls (PCBs), and inorganics. Every sample location was not analyzed for all of the parameters. In general, inorganics were analyzed for at every location (except one Phase I sample where only pesticides were analyzed), and other parameters were analyzed at various locations based on historical knowledge and land use of the site.

2.2 Data Summary and Reduction

A data summary for the positively identified compounds in soils are presented in Table 2-1. The summary table includes the following information:

- The range of detected values.
- The frequency of detection and total number of samples analyzed.
- The range of quantitation limits.
- The arithmetic mean concentration.



Arsenal Stre
246
241
243
311
229
39
656
Wooley Avenue
147
292
100
97
242
Craig Street
Thompson Street
North Beacon Street
Bay Street
Charles River Road
Rubbish
Packer
Trailer
14SUB02
12S
Yacht
Club
Charles
Flow
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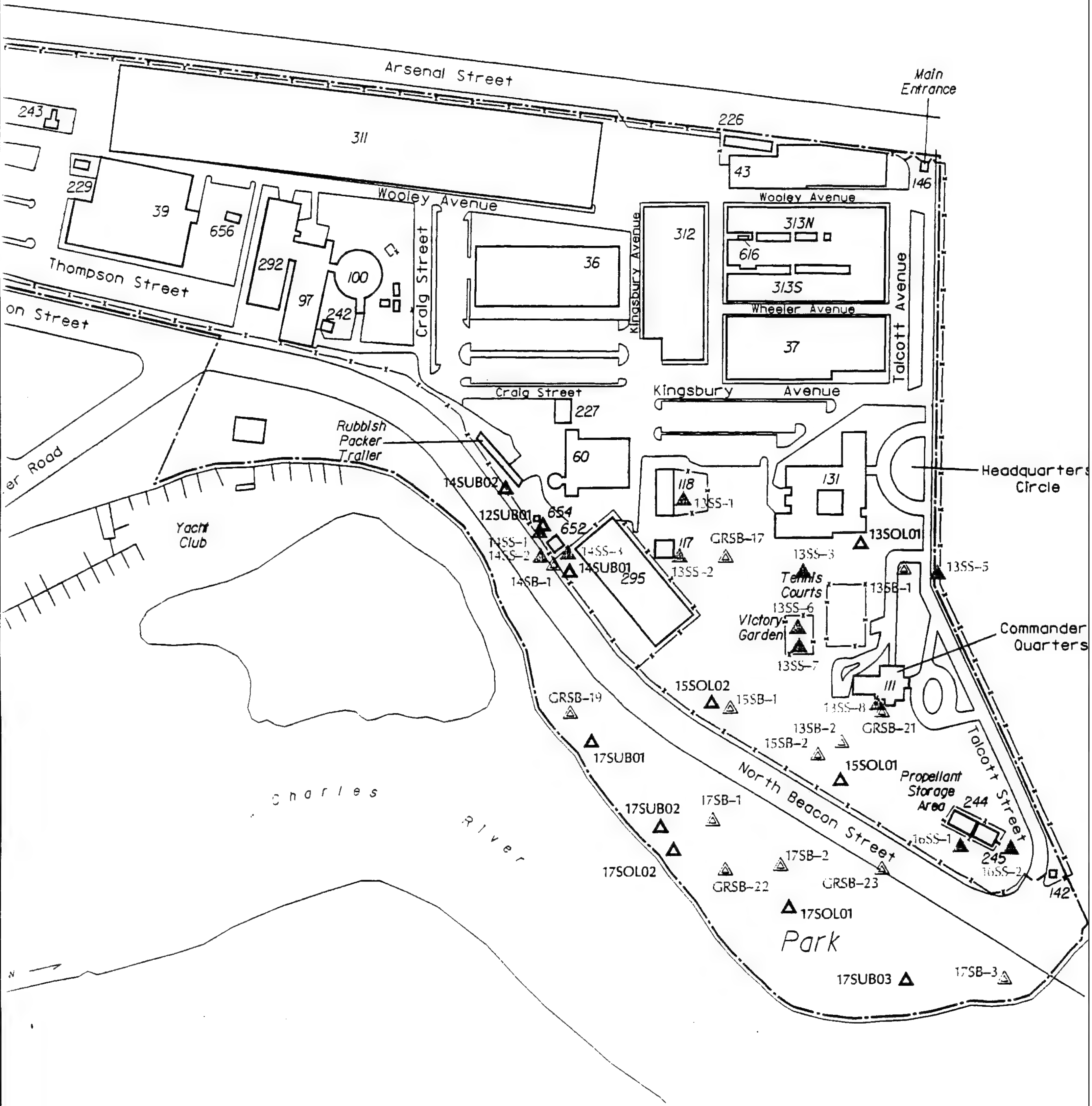
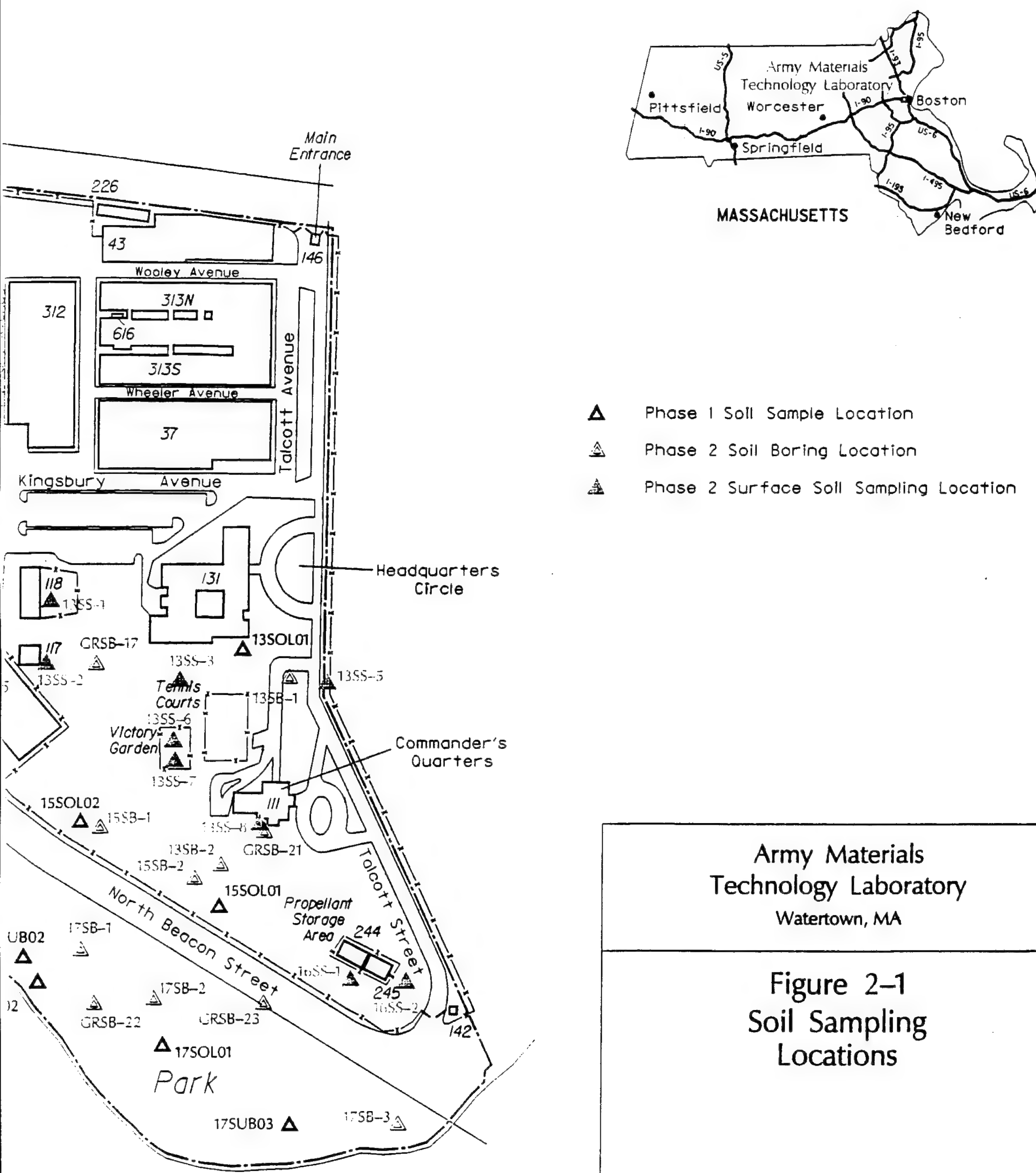


Arsenal Street
Main Entrance
243
311
226
43
146
229
39
656
Wooley Avenue
Thompson Street
on Street
292
97
100
242
Craig Street
36
Kingsbury Avenue
312
313N
616
313S
Wheeler Avenue
37
Talcott Avenue
Craig Street
227
Kingsbury Avenue
Rubbish Packer Trailer
60
er Road
Yacht Club
14SUB02
12SUB01
654
652
118
13SS-1
131
Headquarters Circle
14SS-1
14SS-2
14SS-4
14SUB01
14SB-1
295
117
13SS-2
GRSB-17
13SOL01
13SS-3
Tennis Courts
13SS-5
13SB-1
13SS-6
Victory Garden
13SS-7
Commander Quarters
111
15SOL02
15SB-1
13SS-8
GRSB-21
GRSB-19
17SUB01
13SB-2
15SB-2
15SOL01
Talcott Street
Propellant Storage Area
244
North Beacon Street
Charles River
17SUB02
17SB-1
17SOL02
16SS-1
245
16SS-2
142
17SB-2
GRSB-22
GRSB-23
17SOL01
Park
17SUB03
17SB-3



Army Materials
Technology Laboratory
Watertown, MA

Figure 2–1
Soil Sampling Locations

Scale
0 meters 150
0 feet 500

27–MAR–1995

WESTON

Table 2-1

Chemicals Identified in Soils (0-2 feet)

Chemical	Range of Hits (mg/kg)	Frequency of Detection	Range of Quantitation Limits (mg/kg)	Arithmetic Mean (mg/kg)	Upper 95% Confidence Limit (mg/kg)
Organics					
Acenaphthene	8.40E-02 - 4.79E-01	7 / 28	4.10E-02 - 4.10E+00	4.10E-01	1.37E+00
Acenaphthylene	1.63E-01 - 4.19E+00	9 / 28	3.30E-02 - 4.60E+00	6.32E-01	3.06E+00
Acetone	1.20E-02 - 5.10E-02	5 / 23	1.10E-02 - 3.30E+00	9.38E-01	9.31E+01
Aldrin	6.39E-03 - 7.62E-03	2 / 34	1.40E-03 - 1.30E+00	1.36E-01	1.21E+00
Alpha-Chlordane	5.00E-03 - 1.55E-01	9 / 11	2.00E-03 - 2.00E-03	3.15E-02	3.74E-01
Alpha-Endosulfan	2.48E-03 - 1.42E-02	4 / 33	1.00E-03 - 1.00E+00	1.07E-01	4.12E+00
Anthracene	1.59E+00 - 1.45E+01	4 / 28	5.40E-01 - 5.40E+00	1.39E+00	1.80E+00
Benzene	2.58E-01 - 2.58E-01	1 / 23	3.00E-03 - 1.00E-01	3.80E-02	2.97E-01
Benzo (a) anthracene	2.14E-01 - 3.15E+01	21 / 28	4.10E-02 - 3.00E+00	2.33E+00	7.83E+00
Benzo (a) pyrene	8.27E-01 - 3.66E+01	6 / 28	3.80E-01 - 3.80E+00	2.62E+00	3.63E+00
Benzo (b) fluoranthene	7.13E-01 - 1.54E+01	12 / 28	3.10E-01 - 3.60E+00	1.72E+00	3.94E+00
Benzo (g,h,i) perylene	3.78E-01 - 1.36E+01	13 / 28	1.80E-01 - 2.40E+00	1.53E+00	4.44E+00
Benzo (k) fluoranthene	4.06E-01 - 2.36E+01	15 / 28	1.30E-01 - 8.00E+00	2.30E+00	6.06E+00
Benzyl alcohol	1.29E+00 - 1.29E+00	1 / 28	3.20E-02 - 3.00E+00	3.05E-01	9.54E-01
Beta-Endosulfan	9.12E-04 - 1.31E-02	6 / 33	7.00E-04 - 2.40E+00	5.77E-01	1.43E+02
Butanone, 2-	1.80E-02 - 1.80E-02	1 / 24	1.00E-02 - 4.30E+00	1.17E+00	4.23E+02
Butylbenzyl phthalate	4.76E-01 - 1.10E+00	3 / 29	3.00E-01 - 3.00E+00	9.20E-01	1.23E+00
Chlordane	3.24E-01 - 9.36E+00	16 / 33	6.84E-02 - 3.00E+01	1.67E+00	5.64E+00
Chrysene	7.59E-02 - 3.39E+01	16 / 28	3.20E-02 - 4.50E+00	2.36E+00	1.31E+01
DDD	4.20E-03 - 3.48E+00	16 / 34	2.70E-03 - 6.40E-02	2.41E-01	8.19E-01
DDE	4.48E-03 - 6.33E+00	26 / 34	2.70E-03 - 6.80E-02	5.16E-01	2.57E+00
DDT	1.01E-02 - 5.20E+00	17 / 33	3.50E-03 - 4.10E+00	8.01E-01	4.61E+00
Delta-Hexachlorocyclohexane	2.01E-02 - 3.36E-02	3 / 34	5.00E-03 - 2.10E-01	2.27E-02	4.18E-02
Dibenz (a,h) anthracene	4.68E-01 - 3.34E+00	3 / 28	2.00E-01 - 2.00E+00	3.75E-01	4.65E-01
Dieldrin	7.00E-03 - 3.12E-01	14 / 34	1.60E-03 - 7.90E-02	3.43E-02	9.67E-02
Endrin	1.30E-02 - 5.00E-01	11 / 34	6.50E-03 - 1.30E+00	2.70E-01	4.96E+00
Fluoranthene	1.32E-01 - 5.41E+01	21 / 28	5.20E-01 - 5.20E+00	3.57E+00	5.55E+00
Fluorene	1.59E-01 - 1.05E+00	7 / 28	6.50E-02 - 3.00E+00	3.93E-01	1.05E+00
Gamma-Chlordane	1.40E-02 - 1.73E-01	6 / 11	4.00E-03 - 4.00E-03	3.08E-02	4.92E-01
Heptachlor	1.30E-02 - 1.30E-02	1 / 34	1.00E-03 - 2.40E-01	2.98E-02	1.56E-01
Heptachlor epoxide	2.28E-03 - 1.19E-01	13 / 34	1.30E-03 - 4.80E-01	5.94E-02	3.46E-01
Indeno (1,2,3-cd) pyrene	3.22E-01 - 1.04E+01	5 / 28	2.10E-01 - 2.40E+00	1.87E+00	4.09E+00
Isodrin	3.10E-02 - 3.43E-01	6 / 34	3.00E-03 - 4.80E-01	6.64E-02	4.01E-01
Methoxychlor	5.09E-02 - 4.70E-01	4 / 33	3.59E-02 - 1.00E+01	7.54E-01	2.68E+00
Methylnaphthalene, 2-	6.41E-02 - 3.23E-01	7 / 28	3.20E-02 - 3.00E+00	2.88E-01	7.51E-01
PCB 1260	8.44E-02 - 4.87E+00	6 / 35	4.79E-02 - 7.90E-01	3.15E-01	4.96E-01
Phenanthrene	1.64E-01 - 1.68E+01	18 / 28	3.20E-02 - 4.10E+00	2.64E+00	8.41E+00
Pyrene	1.48E-01 - 5.26E+01	24 / 28	4.20E-01 - 4.20E+00	4.17E+00	7.01E+00
Tetrachloroethene	2.00E-03 - 2.00E-03	1 / 23	2.00E-03 - 1.60E-01	4.57E-02	9.34E-01
Toluene	2.05E-01 - 2.05E-01	1 / 23	7.00E-03 - 1.00E-01	3.66E-02	1.23E-01
Inorganics					
Aluminum	6.68E+03 - 2.48E+04	35 / 35	-	1.42E+04	1.60E+04
Arsenic	3.20E+00 - 5.20E+01	35 / 35	-	1.39E+01	1.69E+01
Barium	2.40E+01 - 3.03E+02	35 / 35	-	6.58E+01	7.34E+01
Beryllium	1.92E-01 - 5.02E+00	23 / 35	4.27E-01 - 6.84E-01	6.45E-01	7.84E-01
Boron	1.06E+01 - 1.06E+01	1 / 3	7.37E+00 - 7.37E+00	5.99E+00	1.83E+02
Cadmium	7.71E-01 - 3.53E+00	4 / 35	4.47E-01 - 1.20E+00	6.92E-01	8.09E-01
Calcium	8.29E+02 - 9.82E+03	35 / 35	-	3.35E+03	4.00E+03
Chromium	1.29E+01 - 7.12E+01	35 / 35	-	2.40E+01	2.68E+01
Cobalt	5.09E+00 - 8.93E+01	35 / 35	-	1.55E+01	1.86E+01
Copper	2.26E+01 - 1.55E+03	35 / 35	-	1.00E+02	1.01E+02
Iron	1.73E+03 - 1.30E+05	35 / 35	-	2.86E+04	3.63E+04
Lead	3.78E+01 - 5.21E+02	33 / 34	5.47E+01 - 5.47E+01	2.13E+02	2.91E+02

Table 2-1 (cont'd.)

Chemicals Identified in Soils (0-2 feet)

Chemical	Range of Hits (mg/kg)	Frequency of Detection	Range of Quantitation Limits (mg/kg)	Arithmetic Mean (mg/kg)	Upper 95% Confidence Limit (mg/kg)
Magnesium	1.73E+03 - 8.34E+03	35 / 35	-	4.07E+03	4.63E+03
Manganese	1.97E+02 - 1.29E+03	35 / 35	-	3.90E+02	4.41E+02
Mercury	6.50E-02 - 5.67E-01	28 / 35	2.80E-02 - 5.00E-02	1.96E-01	4.20E-01
Nickel	1.22E+01 - 9.92E+01	35 / 35	-	2.86E+01	3.38E+01
Potassium	4.86E+02 - 3.80E+03	35 / 35	-	1.16E+03	1.33E+03
Silver	5.50E-02 - 7.94E-01	3 / 35	3.40E-02 - 8.03E-01	3.18E-01	8.53E-01
Sodium	5.31E+01 - 6.93E+02	35 / 35	-	2.15E+02	2.64E+02
Tin	6.61E+00 - 6.61E+00	1 / 10	5.39E+00 - 5.81E+00	3.19E+00	3.79E+00
Uranium	1.51E-01 - 1.51E-01	1 / 10	1.08E-01 - 1.19E-01	6.68E-02	8.12E-02
Vanadium	2.37E+01 - 1.27E+02	35 / 35	-	5.15E+01	5.70E+01
Zinc	5.38E+01 - 8.49E+02	35 / 35	-	1.38E+02	1.57E+02
Cyanide	3.19E-01 - 4.29E-01	3 / 23	2.50E-01 - 5.00E+00	1.19E+00	4.10E+00

- The 95% upper confidence limit (UCL) of the mean concentration (based on log-normal distribution).

The distribution of the data was determined by plotting the data, which indicated that the majority of the chemicals did not display a normal distribution. As a result, the distribution of all chemicals was assumed to be lognormal. The following equation was used to calculate the upper 95% confidence limit of the mean for lognormally distributed data:

$$UCL = e^{(x + 0.5s^2 + sH/\sqrt{n-1})}$$

Where:

UCL	=	Upper 95% confidence limit.
e	=	Constant (base of the natural log, equal to 2.718).
x	=	Mean of the transformed data (log of the geometric mean).
s	=	Standard deviation of the transformed data.
H	=	H-statistic (Gilbert, 1987).
n	=	Number of samples.

In calculating the arithmetic mean and 95% UCL of the mean, non-detects were incorporated as one-half the sample quantitation limit.

2.3 Selection of Chemicals of Potential Concern

Chemicals of potential concern were identified for the terrestrial ecological risk assessment based on a number of criteria including frequency of detection, screening values, and toxicity. In some instances, typical background values were also considered for certain inorganics. Table A-1 in Appendix A presents the rationale for excluding chemicals from the list of chemicals of potential concern. Thirty-one chemicals were screened out based on comparison with screening values. The screening values that were used are presented in Table A-2 (Appendix A), and were calculated based on a Northern short-tailed shrew ingesting soil, as well as earthworms that have accumulated contaminants from the soil. Ingestion rates and body weights for the shrew were obtained from the U.S. Environmental

Protection Agency's (EPA's) Wildlife Exposure Factors Handbook (EPA, 1993), and are discussed further in Subsection 3.4. The equations that were used to calculate the screening levels are presented in Tables A-3 and A-4. These screening values were compared to the maximum detected soil concentrations in the area of concern at the site. If the maximum detected concentrations fell below the screening values, then the chemical was screened out as a chemical of potential concern. There were a few instances where a chemical only slightly exceeded a screening value at a couple of locations (heptachlor epoxide, delta-hexachlorocyclohexane, methoxychlor, cobalt). These chemicals were also screened out.

Calcium, iron, and magnesium did not have screening levels, but were excluded as chemicals of potential concern based on low toxicity, and because the concentrations fell within typical background ranges as presented in Shacklette and Boerngen (1984), Kabata-Pendias and Pendias (1984), and NJDEPE (1992) (See Table A-8). Tin and uranium were excluded due to low frequency of detection and also because the detected concentrations fell within typical background ranges. In addition, uranium is shown to be naturally occurring and not from AMTL, since the ratio of the isotopes U-234/U-238 was approximately 1.0 for the samples taken during the Phase II remedial investigation. The ratio of these two isotopes for depleted uranium, the material used at AMTL, is typically 0.1, because the lighter isotope, U-234, is removed during the depletion process. Although aluminum exceeded screening values, it is a ubiquitous element, and the on-site concentrations fell within typical background levels. Thus, aluminum was also excluded as a chemical of potential concern.

Based on this screening, 17 organics and 8 inorganics were selected as chemicals of potential concern, and are presented in Table 2-2.

Table 2-2

Chemicals of Potential Concern

Organics	Inorganics
Aroclor 1260	Arsenic
Chlordane	Cadmium
DDD	Chromium
DDE	Copper
DDT	Lead
Dieldrin	Manganese
Endrin	Nickel
PAHs	Zinc
Benzo(a)anthracene	
Benzo(a)pyrene	
Benzo(b)fluoranthene	
Benzo(g,h,i)perylene	
Benzo(k)fluoranthene	
Chrysene	
Dibenz(a,h,)anthracene	
Fluoranthene	
Indeno(1,2,3-cd)pyrene	
Pyrene	

3.0 EXPOSURE CHARACTERIZATION

The objectives of the exposure assessment are to:

- Identify habitats that have received or may receive chemicals from the site.
- Identify the plants and terrestrial wildlife that may be potentially exposed to the chemicals of potential concern.
- Select indicator or target species/communities.
- Identify significant pathways/routes by which target species are potentially exposed.
- Predict exposure doses for selected target species.

In characterizing ecological exposure, the potential magnitude and frequency by which ecological receptors are exposed to chemicals of potential concern are evaluated. In addition, the characterization evaluates all routes of exposure (*e.g.*, soil ingestion, plant ingestion) by which species inhabiting impacted areas may be exposed.

3.1 Habitat Evaluation

The initial step in characterizing exposure is to identify the on-site habitats that may be affected by the chemicals of potential concern, and subsequently, to determine appropriate receptor organisms for those habitats.

The location of the site and surrounding vicinity is shown in Figure 1-1. A more detailed map of the site is presented in Figure 2-1. The AMTL Site currently occupies 36.5 acres and is located in an urban area. The site, located on a former low bluff of the river, is generally flat, sloping slightly toward the river. As a result of more than a century of construction, most of the original topography has been covered by sand and gravel fill and construction debris. The majority of the AMTL site has limited potential as ecological habitat. Suitable habitat for terrestrial vegetation and wildlife is restricted to the southeast corner of the site, which is bordered by the Charles River to the south and west, by Talcott

Street to the east, and by a series of structures near the Commander's Quarters to the north (Figure 2-1). Because of the limited, lower quality habitat provided by the industrialized portion of the property, this ecological assessment focuses on the "southeast sector" of the site. This area encompasses approximately 11 acres, and includes a park, which is located between the Charles River and North Beacon Street, and consists of wooded areas as well as open grassy fields. The area to the north of North Beacon Street contains wooded sections along the roadways, as well as an open grassy area in the vicinity of the Commander's Quarters.

The open field and wooded areas identified on the site are locations where ecological receptors may be exposed to chemicals. The analytical results from the remedial investigation at the site show that chemicals of potential concern have been detected in soils in these areas. Appropriate ecological receptors are selected for evaluation, based on the potentially affected habitats at the site, chemical characterization of the site, and other site-specific considerations.

3.2 Selection of Indicator Species/Communities and Pathways of Exposure

This subsection presents the basis for the selection of indicator species and communities for evaluation in this assessment. In addition, exposure pathways are selected for each of the indicator species based on the assessment of the habitat types and the known chemical distributions at the site. All exposure pathways that are of little or no concern based on the analysis of site characteristics are eliminated. Emphasis is given to those pathways and species considered critical to the evaluation of ecological risk at the site.

The principal criteria used to select appropriate indicator species include:

- Species that occur on the site.
- Species that are threatened, endangered, or of special concern.
- Species that are critical to the structure and function of the particular ecosystem they inhabit.

- Species that serve as indicators of an important change in the ecosystem.
- Species that have a realistic and significant potential for exposure.
- Species for which sufficient exposure and/or toxicity data are available for evaluation.

Even though indicator species are selected for evaluation in the risk assessment, these species also represent the exposure that other similar species with comparable feeding habits may be receiving, and thus, serve as surrogate species.

Factors that have gone into the exposure pathway selection process include:

- Local topography.
- Local land use.
- Site-specific habitat conditions.
- Surrounding terrestrial habitat.
- Review of contaminant migration.
- Persistence and mobility of migrating pollutants.

The subsections that follow discuss the justification for the selection of indicator species and communities, as well as the selection of potential exposure routes.

3.2.1 Terrestrial Wildlife

In this assessment, it is assumed that exposure of terrestrial wildlife to the chemicals of potential concern occurs primarily when the animals feed in those areas affected by site contamination. Avian and mammalian species with the greatest potential for exposure were selected for evaluation. Species selected were representative of the principal habitat types present at the site. In addition, species were selected that represented a range of feeding relationships within these habitats. Although wildlife present at the AMTL Site may be exposed to the chemicals of potential concern through routes other than ingestion (*i.e.*, dermal absorption and inhalation), there is little scientific information available with which to assess these types of exposures. Therefore, these routes of exposure will not be evaluated in this assessment.

Mammalian Species

The Northern short-tailed shrew (*Blarina brevicauda*) was selected as an indicator mammalian species for numerous reasons, including its almost exclusive insectivorous feeding habits, its limited home range (0.5 to 1.0 acre) (Burt and Grossenheider, 1980; Merritt, 1987), and its burrowing habits (makes tunnels into ground and snow). The short-tailed shrew is a commonly found species in New England (DeGraaf and Rudis, 1986), and is an inhabitant of forests, grasslands, marshes, and brushy areas (Merritt, 1987). Thus, the site is expected to provide adequate habitat for the shrew. In addition, the shrew is representative of the small mammal community that exists at the site. The shrew was evaluated for exposure to chemicals in soils through the ingestion of soil invertebrates (*i.e.*, earthworms) that may accumulate chemicals from their environment as well as through the incidental ingestion of soils while feeding, burrowing, and preening.

The white-footed mouse (*Peromyscus leucopus*) was also evaluated as an indicator species. The white-footed mouse was chosen due to its herbivorous diet, its limited home range (0.1 to 2.5 acres) (Burt and Grossenheider, 1980; Merritt, 1987), and because the site contains suitable habitat for this mouse. The white-footed mouse is most abundant in habitat that includes a canopy, such as brushy field and deciduous woodlots (EPA, 1993). The affected terrestrial habitats found on the AMTL property include both brushy and wooded areas. Both these areas on the site are expected to provide adequate habitat for the white-footed mouse. The white-footed mouse was evaluated for exposure to chemicals through the ingestion of vegetation that may accumulate chemicals from soil, as well as through the incidental ingestion of soils while feeding, burrowing, and preening.

Avian Species

The American robin (*Turdus migratorius*) was chosen as an indicator species for passerine (*i.e.*, perching) birds in this assessment. The robin is expected to be one of the maximally exposed bird species at the site because of the potential for exposure to chemicals through the ingestion of invertebrates, particularly earthworms, which make up a large percentage

of its diet. In addition, the robin has a limited home range, from 0.11 to 0.75 acres (Young, 1951; Collins and Boyajian, 1965), and thus could be expected to obtain much of its dietary intake from the site. The robin is also a potential year-round resident at the site, and is representative of several predominantly ground-foraging omnivorous species potentially inhabiting the site. The robin was evaluated for exposure to chemicals in soils through the ingestion of soil invertebrates (*i.e.*, earthworms) that may accumulate chemicals from their environment, as well as through the incidental ingestion of soils while feeding.

The song sparrow (*Melospiza melodia*) was chosen for evaluation because it has been observed as a common breeder in the site vicinity (R. Stymeist, 1995; see Appendix D). In addition, the song sparrow has the potential for bioaccumulation of chemicals through the ingestion of plant material at the site, particularly seeds, which make up a large percentage of its diet. The song sparrow is also a potential year-round resident at the site, and is representative of several seed-eating bird species potentially inhabiting the site. The song sparrow was evaluated for exposure to chemicals in soils through the ingestion of seeds that may accumulate chemicals from their environment. In addition, the potential for exposure to chemicals through the incidental ingestion of soils while feeding was evaluated.

3.2.2 Terrestrial Vegetation

The terrestrial vegetation at the site consists primarily of grasses, shrubs, and deciduous trees. Chemicals in soil can enter a plant through four major pathways, including root uptake and translocation to aboveground plant parts; uptake from vapor; uptake from external contamination (dust and soil); and uptake and transport in oil cells (Bell, 1992). A direct comparison of soil concentrations with available phytotoxicity data was used to assess potential adverse effects on terrestrial vegetation.

3.2.3 Soil Invertebrates

Soil invertebrates, such as earthworms, are ecologically important because of their role in a number of processes including soil aeration, soil drainage, and soil fertility (EPA, 1992b).

Soil invertebrates can be exposed to contaminants in the soil through dermal absorption and soil ingestion. A direct comparison of soil concentrations with available soil invertebrate toxicity data was used to assess potential adverse effects on soil invertebrates.

3.2.4 Endangered and Threatened Species

The Massachusetts Natural Heritage Society was contacted for information regarding potential endangered and threatened species in the vicinity of the site. The review found that there were no records of rare terrestrial or aquatic species or significant plant communities within the site area (Massachusetts Division of Fisheries and Wildlife, 1995).

3.2.5 Summary

A summary of all exposure routes for each of the selected indicator species or communities is presented in Table 3-1.

3.3 Exposure Concentrations

Areas of exposure are selected for the indicator species/communities based on the assessment of habitats and the known distribution of the chemicals at the site. The concentrations at these areas of exposure are important in determining exposure doses and subsequent risk to receptors. Two exposure concentrations were used in assessing risk to birds and mammals - (1) the arithmetic mean, and (2) the 95% upper confidence limit (UCL) of the mean, or the maximum detected concentration, whichever value was lower. Both the arithmetic mean and 95% UCL were used to represent average exposure concentrations. The 95% UCL is presented in addition to the arithmetic mean because of the uncertainty associated with estimating the true average concentration at a site. Averages are used as the exposure concentrations since they are most representative of the concentration that would be contacted by mobile organisms at the site (EPA, 1992d). For

Table 3-1

Exposure Routes of Potential Concern to Ecological Receptors

Indicator Species and Communities

Northern short-tailed shrew (*Blarina brevicauda*)

- Ingestion of soil invertebrates (*i.e.*, earthworms)
- Incidental ingestion of soil

White-Footed Mouse (*Peromyscus leucopus*)

- Ingestion of vegetation (*i.e.*, seeds)
- Incidental ingestion of soil

American Robin (*Turdus migratorius*)

- Ingestion of soil invertebrates (*i.e.*, earthworms)
- Incidental ingestion of soil

Song Sparrow (*Melospiza melodia*)

- Ingestion of vegetation (*i.e.*, seeds)
- Incidental ingestion of soil

Terrestrial Plants

- Direct contact with soil
- Absorption/concentration from soil (seeds)

Soil Invertebrates

- Direct contact with soil
- Absorption/concentration from soil

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stationary organisms (*e.g.*, plants), or organisms that would be expected to be found in a relatively small area (*i.e.*, soil invertebrates), each sample location was evaluated as a potential exposure concentration.

The exposure concentrations were based on soils data collected from 0-0.5 feet, 0.5-1.5 feet, and 0-2 feet. These soils were collected at the surface or near-surface, and represent the soil depths most likely to be contacted by ecological receptors. The exposure concentrations used in this assessment are presented in Table 3-2. As discussed in Subsection 2.2, the data were assumed to be lognormally distributed.

3.4 Estimation of Exposure Doses

This subsection discusses the methods by which chemical intakes are estimated for the selected indicator species. The models used to estimate exposure doses in milligrams of contaminant intake per kilogram of body weight per day (mg/kg-day) for the Northern short-tailed shrew, white-footed mouse, American robin, and song sparrow are presented here.

3.4.1 Northern Short-Tailed Shrew

Primary routes of potential exposure to the short-tailed shrew include the ingestion of soil invertebrates and the incidental ingestion of surface soil. The methodology used to calculate the exposure for the shrew and the associated assumptions are presented in the following paragraphs.

Ingestion of Soil Invertebrates

Diets are variable among species of shrew, but in general, they are composed of earthworms, insects, and other invertebrates (DeGraaf and Rudis, 1986). The composition and quantity of the diet of the shrew can also vary with season and availability of resources as well as health, age, and sex of the species. For this assessment potential exposure to the

Table 3-2
Exposure Concentrations (mg/kg)

Chemical	Soil Concentration (mg/kg)	
	Mean	Upper 95% Confidence Limit
Organics		
Chlordane	1.67E+00	5.64E+00
DDD	2.41E-01	8.19E-01
DDE	5.61E-01	2.57E+00
DDT	8.01E-01	4.61E+00
Dieldrin	3.43E-02	9.67E-02
Endrin	2.70E-01	5.00E-01[a]
PAHs		
Benzo(a)anthracene	2.33E+00	7.83E+00
Benzo(a)pyrene	2.62E+00	3.63E+00
Benzo(b)fluoranthene	1.72E+00	3.94E+00
Benzo(g,h,i)perylene	1.53E+00	4.44E+00
Benzo(k)fluoranthene	2.30E+00	6.06E+00
Chrysene	2.36E+00	1.31E+01
Dibenz(a,h,)anthracene	3.75E-01	4.65E-01
Fluoranthene	3.57E+00	5.55E+00
Indeno(1,2,3-cd)pyrene	1.87E+00	4.09E+00
Pyrene	4.17E+00	7.01E+00
PCB (Aroclor 1260)	3.15E-01	4.96E-01
Inorganics		
Arsenic	1.39E+01	1.69E+01
Cadmium	6.92E-01	8.09E-01
Chromium	2.41E+01	2.68E+01
Copper	1.00E+02	1.01E+02
Lead	2.13E+02	2.91E+02
Manganese	3.90E+02	4.41E+02
Nickel	2.86E+01	3.38E+01
Zinc	1.38E+02	1.57E+02

[a] This value represents the maximum detected concentration.

short-tailed shrew from chemicals of concern in its daily diet was evaluated for the consumption of earthworms. Although the diet of the shrew does not consist entirely of earthworms, the earthworm was used to represent a typical soil invertebrate potentially ingested by the shrew since, (1) the earthworm is one of the few invertebrates for which chemical uptake can be estimated, and (2) earthworms would be expected to significantly bioaccumulate chemicals found in the soil as a result of both dermal absorption and soil ingestion. Because earthworms demonstrate a higher potential for bioaccumulation than other soil invertebrates, it is likely that the use of earthworms represents a conservative estimate of the potential exposure to the shrew.

The exposure doses to the short-tailed shrew through ingestion of earthworms were determined using the approach and assumptions as presented in Table 3-3. The estimation of chemical concentrations in earthworms is discussed in Appendix B. The daily earthworm ingestion rate for the short-tailed shrew was assumed to be 0.62 g wet weight/g body weight per day based on information for male and female adult short-tailed shrews which were fed a diet of beef liver (EPA, 1993). Assuming a mean body weight of 15 grams for an adult short-tailed shrew (EPA, 1993), a wet weight ingestion rate of 9.3 grams was estimated. A dry weight dietary intake of 2.8 g/day was estimated from the wet weight ingestion rate of 9.3 g/day, based on a water content of 69.7% in the study diet (*i.e.*, beef liver) (Baes et al., 1984). The wet weight ingestion rate of 9.3 g/day or 0.62 g/g/day is similar to ingestion rates reported for the short-tailed shrew in other sources (Opresko et al., 1994; Churchill, 1990). Baker (1983), however, reported that short-tailed shrews consume 50 -300% of their body weight per day in food. This is a higher ingestion rate than was reported in other references, and is assessed in the Uncertainty Analysis (Section 6).

The home range of the short-tailed shrew ranges from 0.5 to 1 acre (Burt and Grossenheider, 1980; Merritt, 1987). Since this falls within the area of the site, it was assumed that 100% of the shrew's forage would be obtained from within the boundaries of the site.

Table 3-3

Model for Calculating Doses to the Northern Short-Tailed Shrew Through the Ingestion of Earthworms

$$\text{Earthworm Ingestion Dose (mg/kg-day)} = \frac{CE \times IR \times FI}{BW \times CF}$$

Where:

CE	=	Chemical concentration in earthworms (mg/kg)
IR	=	Earthworm ingestion rate (g dry weight/day)
FI	=	Fraction ingested from contaminated source (unitless)
BW	=	Body weight (kg)
CF	=	Conversion factor (g/kg)

Exposure Assumptions

CE	=	Earthworm concentrations (mg/kg) are presented in Table B-2 (Appendix B).
IR	=	2.8 g dry weight/day (EPA, 1993)
FI	=	1[a]
BW	=	0.015 kg (EPA, 1993)
CF	=	1000 g/kg

[a]Assumes home range of the shrew falls within the site area.

Incidental Ingestion of Soil

The short-tailed shrew may also be exposed to chemicals through the incidental ingestion of surface soil. Mammals with feeding and burrowing habits, such as the shrew can inadvertently ingest surface soil while consuming soil invertebrates or while preening or burrowing. The model and assumptions used to estimate exposure doses to the short-tailed shrew through soil ingestion is presented in Table 3-4.

Data regarding the incidental soil ingestion rate of the short-tailed shrew were not available. EPA (1993) reports that the percent soil in the diet of a woodcock, which feeds extensively on earthworms, is approximately 10.4%. EPA (1993) further suggests that other species that ingest earthworms might be expected to have similar soil intakes. A best estimate of 10.4% of the dry weight dietary ingestion rate was used for the short-tailed shrew's incidental soil ingestion rate. A dry weight soil ingestion rate of 0.29 g/day was calculated for the shrew based on 10.4% of its dry weight dietary intake of 2.8 g/day.

Total Exposure to the Northern Short-tailed Shrew

Based on the previous discussion, the total exposure of the shrew to chemicals from the site was derived as follows:

$$Dose_{Total} = Dose_{worm} + Dose_{soil}$$

Where:

$Dose_{Total}$	=	Total dose (mg/kg-day).
$Dose_{worm}$	=	Dose from ingestion of earthworms (mg/kg-day).
$Dose_{soil}$	=	Dose from soil ingestion (mg/kg-day).

The total and route-specific exposure doses estimated for the shrew are presented in Table 3-5.

Table 3-4

Model for Calculating Doses to the Northern Short-Tailed Shrew Through the Incidental Ingestion of Soil

$$\text{Soil Ingestion Dose (mg/kg-day)} = \frac{CS \times SIR \times FI}{BW \times CF}$$

Where:

CS	=	Chemical concentration in surface soil (mg/kg)
SIR	=	Soil ingestion rate (g dry weight/day)
FI	=	Fraction ingested from contaminated source (unitless)
BW	=	Body weight (kg)
CF	=	Conversion factor (g/kg)
Exposure Assumptions		
CS	=	Surface soil concentrations (mg/kg) are presented in Table 2-1.
SIR	=	0.29 g dry weight/day[a]
FI	=	1[b]
BW	=	0.015 kg (EPA, 1993)
CF	=	1000 g/kg

[a]Assumed to be 10.4% of food intake (EPA, 1993).
[b]Assumes home range of the shrew falls within the site area.

Table 3-5

Exposure Doses Estimated for the Northern Short-Tailed Shrew (mg/kg-day)

Chemical	Soil Ingestion Dose		Earthworm Ingestion Dose		Total Dose	
	Mean	95% UCL	Mean	95% UCL	Mean	95% UCL
Organics						
Chlordane	3.23E-02	1.09E-01	1.56E+00	5.26E+00	1.59E+00	5.37E+00
DDD	4.66E-03	1.58E-02	3.73E-01	1.27E+00	3.78E-01	1.28E+00
DDE	1.08E-02	4.97E-02	7.75E-01	3.55E+00	7.86E-01	3.60E+00
DDT	1.55E-02	8.91E-02	1.58E+00	9.12E+00	1.60E+00	9.21E+00
Dieldrin	6.63E-04	1.87E-03	6.34E-02	1.79E-01	6.40E-02	1.81E-01
Endrin	5.22E-03	9.67E-03	1.81E-01	3.36E-01	1.87E-01	3.46E-01
PAHs (total)	4.42E-01	1.08E+00	1.41E+00	3.47E+00	1.85E+00	4.55E+00
Benzo(a)anthracene	4.50E-02	1.51E-01	1.17E-01	3.95E-01	1.62E-01	5.46E-01
Benzo(a)pyrene	5.07E-02	7.02E-02	1.66E-01	2.30E-01	2.17E-01	3.01E-01
Benzo(b)fluoranthene	3.33E-02	7.62E-02	6.74E-02	1.54E-01	1.01E-01	2.31E-01
Benzo(g,h,i)perylene	2.96E-02	8.58E-02	4.28E-02	1.24E-01	7.24E-02	2.10E-01
Benzo(k)fluoranthene	4.45E-02	1.17E-01	9.02E-02	2.38E-01	1.35E-01	3.55E-01
Chrysene	4.56E-02	2.53E-01	1.94E-01	1.08E+00	2.39E-01	1.33E+00
Dibenz(a,h)anthracene	7.25E-03	8.99E-03	3.43E-02	4.25E-02	4.16E-02	5.15E-02
Fluoranthene	6.90E-02	1.07E-01	2.47E-01	3.83E-01	3.16E-01	4.91E-01
Indeno(1,2,3-cd)pyrene	3.62E-02	7.91E-02	1.43E-01	3.13E-01	1.79E-01	3.92E-01
Pyrene	8.06E-02	1.36E-01	3.04E-01	5.10E-01	3.84E-01	6.46E-01
PCB (Aroclor 1260)	6.09E-03	9.59E-03	1.29E+00	2.04E+00	1.30E+00	2.05E+00
Inorganics						
Arsenic	2.69E-01	3.27E-01	1.25E-01	1.51E-01	3.93E-01	4.78E-01
Cadmium	1.34E-02	1.56E-02	5.94E-01	6.95E-01	6.08E-01	7.10E-01
Chromium	4.64E-01	5.18E-01	3.45E+00	3.85E+00	3.91E+00	4.37E+00
Copper	1.93E+00	1.95E+00	8.21E+00	8.30E+00	1.01E+01	1.02E+01
Lead	4.12E+00	5.63E+00	2.11E+01	2.88E+01	2.52E+01	3.44E+01
Manganese	7.54E+00	8.53E+00	8.01E+00	9.06E+00	1.55E+01	1.76E+01
Nickel	5.53E-01	6.53E-01	9.61E+00	1.14E+01	1.02E+01	1.20E+01
Zinc	2.67E+00	3.04E+00	2.55E+02	2.90E+02	2.58E+02	2.93E+02

3.4.2 White-Footed Mouse

Primary routes of potential on-site exposure for the white-footed mouse include the ingestion of plant material (*i.e.*, seeds) and incidental ingestion of soil. The methodology used to calculate the various exposures to the mouse and the associated assumptions are presented in the following paragraphs.

<u>**Ingestion of Plant Seeds**</u>

The diet of the white-footed mouse consists mainly of seeds, nuts, and insects (Burt and Grossenheider, 1976). The composition and quantity of a white-footed mouse's diet can vary with season and availability of resources as well as health, age, and sex of the species (Chapman and Feldhamer, 1982). However, for this assessment, potential exposure to the white-footed mouse from chemicals of potential concern in its daily diet was only evaluated for the consumption of plant seeds. Sufficient information does not exist with which to estimate chemical uptake in other dietary items. Because the mouse's reported home range of 0.1 to 2.5 acres (Burt and Grossenheider, 1980; Merritt, 1987) is less than the total area of the site, 100% of the mouse's foraging time is assumed to occur in contaminated areas. The exposure doses to the white-footed mouse through ingestion of seeds were determined using the approach and assumptions as presented in Table 3-6. The ingestion rate for white-footed mice was assumed to be 0.2 g wet weight/g body weight per day, which is the midpoint of the reported range (0.18 - 0.22 g/g-day) for nonbreeding adult deer mice (*Peromyscus maniculatus*) (EPA, 1993). The white-footed mouse and deer mouse are morphologically, behaviorally, and ecologically similar (Wolff, 1985), and thus it was assumed that their ingestion rates would also be similar. The midpoint of the body weights reported for adult white-footed mice was 20 g (based on a range of 13 to 27 g) (Merritt, 1987). Thus, a daily wet weight ingestion rate of 4 g/day was estimated. A dry weight dietary intake of 3.9 g/day was estimated from the wet weight ingestion rate, based on a water content of 3% in the laboratory rat chow diet (EPA, 1993). The estimation of chemical concentrations in plant seeds is discussed further in Appendix C.

Table 3-6

Model for Calculating Doses to the White-Footed Mouse Through the Ingestion of Plant Seeds

$$\text{Seed Ingestion Dose (mg/kg-day)} = \frac{CS \times SIR \times FI}{BW \times CF}$$

Where:

CS	=	Chemical concentration in seeds (mg/kg dry weight)
SIR	=	Seed ingestion rate (g dry weight/day)
FI	=	Fraction ingested from contaminated source (unitless)
BW	=	Body weight (kg)
CF	=	Conversion factor (g/kg)
Exposure Assumptions		
CS	=	Seed concentrations (mg/kg) are presented in Table C-2 (Appendix C).
SIR	=	3.9 g dry weight/day (EPA, 1993)
FI	=	1[a]
BW	=	0.020 kg (Merritt, 1987)
CF	=	1000 g/kg

[a]Assumes home range of the mouse falls within the site area.

Incidental Ingestion of Soil

The white-footed mouse may also be exposed to chemicals through the incidental ingestion of surface soil. Mammals with ground foraging and nesting habits such as the white-footed mouse tend to have increased exposure to surface soils. Therefore, it was assumed that the mouse may inadvertently ingest surface soil while consuming plant seeds or while preening, nesting, or foraging. The exposure doses to the white-footed mouse through incidental ingestion of soil were determined using the approach and assumptions as presented in Table 3-7.

It has been estimated that less than 2% of the dry weight dietary intake of the white-footed mouse consists of soil (EPA, 1993). For this assessment it was assumed that soil intake is 2% of the dietary intake. A dry weight soil ingestion rate of 0.078 g/day was calculated for the deer mouse based on 2% of its dry weight dietary intake of 3.9 g/day.

Total Exposure to the White-Footed Mouse

Based on the previous discussion, the total exposure of the white-footed mouse to chemicals from the site was derived as follows:

$$Dose_{Total} = Dose_{plant} + Dose_{soil}$$

Where:

$Dose_{Total}$	=	Total dose (mg/kg-day).
$Dose_{plant}$	=	Dose from ingestion of plant seeds (mg/kg-day).
$Dose_{soil}$	=	Dose from soil ingestion (mg/kg-day).

The total and route-specific exposure doses estimated for the white-footed mouse are presented in Table 3-8.

Table 3-7

Model for Calculating Doses to the White-Footed Mouse Through the Incidental Ingestion of Soil

$$\underset{\text{(mg/kg-day)}}{\text{Soil Ingestion Dose}} = \frac{CS \times SIR \times FI}{BW \times CF}$$

Where:		
CS	=	Chemical concentration in surface soil (mg/kg)
SIR	=	Soil ingestion rate (g dry weight/day)
FI	=	Fraction ingested from contaminated source (unitless)
BW	=	Body weight (kg)
CF	=	Conversion factor (g/kg)
Exposure Assumptions		
CS	=	Surface soil concentrations (mg/kg) are presented in Table 2-1.
SIR	=	0.078 g dry weight/day[a]
FI	=	1[b]
BW	=	0.020 kg (Merritt, 1987)
CF	=	1000 g/kg

[a]Assumed to be 2% of food intake (EPA, 1993).
[b]Assumes home range of the white-footed mouse falls within the site area.

Table 3-8

Exposure Doses Estimated for the White-footed Mouse (mg/kg-day)

Chemical	Soil Ingestion Dose		Seed Ingestion Dose		Total Dose	
	Mean	95% UCL	Mean	95% UCL	Mean	95% UCL
Organics						
Chlordane	6.51E-03	2.20E-02	3.12E-01	1.05E+00	3.18E-01	1.07E+00
DDD	9.40E-04	3.19E-03	6.30E-04	2.14E-03	1.57E-03	5.33E-03
DDE	2.19E-03	1.00E-02	2.36E-03	1.08E-02	4.55E-03	2.08E-02
DDT	3.12E-03	1.80E-02	9.01E-03	5.19E-02	1.21E-02	6.98E-02
Dieldrin	1.34E-04	3.77E-04	2.33E-03	6.56E-03	2.46E-03	6.94E-03
Endrin	1.05E-03	1.95E-03	1.83E-02	3.39E-02	1.94E-02	3.59E-02
PAHs (total)	8.91E-02	2.19E-01	2.13E-01	3.93E-01	3.02E-01	6.12E-01
Benzo(a)anthracene	9.09E-03	3.05E-02	1.00E-02	3.37E-02	1.91E-02	6.43E-02
Benzo(a)pyrene	1.02E-02	1.42E-02	9.04E-02	1.25E-01	1.01E-01	1.39E-01
Benzo(b)fluoranthene	6.71E-03	1.54E-02	4.09E-03	9.37E-03	1.08E-02	2.47E-02
Benzo(g,h,i)perylene	5.97E-03	1.73E-02	1.99E-03	5.78E-03	7.96E-03	2.31E-02
Benzo(k)fluoranthene	8.97E-03	2.36E-02	5.47E-03	1.44E-02	1.44E-02	3.81E-02
Chrysene	9.20E-03	5.11E-02	1.02E-02	5.65E-02	1.94E-02	1.08E-01
Dibenz(a,h)anthracene	1.46E-03	1.81E-03	1.00E-03	1.24E-03	2.46E-03	3.06E-03
Fluoranthene	1.39E-02	2.16E-02	3.97E-02	6.17E-02	5.36E-02	8.33E-02
Indeno(1,2,3-cd)pyrene	7.29E-03	1.60E-02	2.44E-03	5.33E-03	9.73E-03	2.13E-02
Pyrene	1.63E-02	2.73E-02	4.76E-02	8.00E-02	6.38E-02	1.07E-01
PCB (Aroclor 1260)	1.23E-03	1.93E-03	7.00E-04	1.10E-03	1.93E-03	3.04E-03
Inorganics						
Arsenic	5.42E-02	6.59E-02	1.63E-02	1.98E-02	7.05E-02	8.57E-02
Cadmium	2.70E-03	3.16E-03	2.02E-02	2.37E-02	2.29E-02	2.68E-02
Chromium	9.36E-02	1.05E-01	2.11E-02	2.35E-02	1.15E-01	1.28E-01
Copper	3.90E-01	3.94E-01	4.88E+00	4.92E+00	5.27E+00	5.32E+00
Lead	8.31E-01	1.13E+00	3.74E-01	5.11E-01	1.20E+00	1.65E+00
Manganese	1.52E+00	1.72E+00	3.80E+00	4.30E+00	5.32E+00	6.02E+00
Nickel	1.12E-01	1.32E-01	3.35E-01	3.95E-01	4.46E-01	5.27E-01
Zinc	5.38E-01	6.12E-01	2.42E+01	2.76E+01	2.48E+01	2.82E+01

3.4.3 American Robin

The primary routes of potential on-site exposure that were evaluated for the American robin include the ingestion of soil invertebrates and the incidental ingestion of soil. The methodology used to calculate the exposure doses for the robin and the associated assumptions are presented in the following paragraphs.

Ingestion of Soil Invertebrates

The American robin, like most members of the thrush family (Turdinae), is primarily a ground forager and feeds on fruits, insects and earthworms (Graber et al., 1971). For this assessment potential exposure to the robin from chemicals of concern in its diet was evaluated based on the consumption of earthworms. Although the diet of the robin does not consist entirely of earthworms, for this assessment it is assumed that earthworms are the primary source of all dietary exposure. The primary reasons for making this assumption are: (1) the earthworm is one of the few invertebrates for which chemical uptake can be estimated, and (2) earthworms would be expected to significantly bioaccumulate chemicals found in the soil as a result of both dermal absorption and soil ingestion. Because earthworms demonstrate a higher potential for bioaccumulation than other soil invertebrates, it is likely that the use of earthworms represents a conservative estimate of the potential exposure to the American robin.

The model and assumptions used to estimate daily doses for the robin based on ingestion of chemicals of concern in invertebrates (*i.e.*, earthworms) are shown in Table 3-9. In a study by Nagy (1987), field metabolic rates for approximately 10 species of passerine birds were analyzed. Body weights were strongly correlated to bird metabolic rates. In determining an appropriate ingestion rate for the robin, the following model from Nagy (1987) was used to represent the relationship between field metabolic rate and body weight:

Table 3-9

Model for Calculating Doses to the American Robin Through the Ingestion of Earthworms

$$\text{Earthworm Ingestion Dose (mg/kg-day)} = \frac{CE \times IR \times FI}{BW \times CF}$$

Where:

CE	=	Chemical concentration in earthworms (mg/kg)
IR	=	Earthworm ingestion rate (g dry weight/day)
FI	=	Fraction ingested from contaminated source (unitless)
BW	=	Body weight (kg)
CF	=	Conversion factor (g/kg)

Exposure Assumptions

CE	=	Earthworm concentrations (mg/kg) are presented in Table B-2 (Appendix B).
IR	=	16 g dry weight/day (Nagy, 1987; EPA, 1993)
FI	=	1[a]
BW	=	0.077 kg (Dunning, 1984)
CF	=	1000 g/kg

[a]Assumes home range of the robin falls within the site area.

$$FMR = 2.123 \times BW^{0.749}$$

Where,

FMR = Field metabolic rate (kcal/day)

BW = Body weight (g)

Assuming an average robin body weight of 77 grams (Dunning, 1984), a field metabolic rate of approximately 55 kcal/day was calculated. In order to convert this field metabolic rate to an ingestion rate, information on the energy content in earthworms was used. The gross energy content of earthworms is approximately 4.6 kcal/g dry weight (EPA, 1993). The amount of metabolizable energy in an earthworm is equal to the gross energy multiplied by an assimilation efficiency factor. Although an assimilation efficiency factor was not available for earthworms, assimilation efficiency values of 72-79% have been reported for animal matter in the diet of birds (EPA, 1993). The midpoint of these range of values (76%) was assumed for earthworms. Thus, the amount of metabolizable energy in an earthworm was estimated to be 3.5 kcal/g dry weight. Based on this information, a dry weight ingestion rate of 16 g/day was estimated for the robin (*i.e.*, 55 kcal/day ÷ 3.5 kcal/g). The calculation of chemical concentrations in earthworms is presented in Appendix B.

The dietary intake of the robin is assumed to occur solely in contaminated areas for each of the sites, because the robin's home range of 0.11 to 0.75 acres is less than the total area of the site (Collins and Boyajan, 1965; Young, 1951).

Incidental Ingestion of Soil

The robin may ingest soil inadvertently while consuming earthworms and other ground-dwelling prey, and while preening. The model and assumptions used to calculate a soil ingestion dose for the robin are presented in Table 3-10.

Data regarding the incidental soil ingestion rate of the American robin were not available. EPA (1993) reports that the percent soil in the diet of a woodcock, which feeds extensively

Table 3-10

Model for Calculating Doses to the American Robin Through the Incidental Ingestion of Soil

$$\text{Soil Ingestion Dose (mg/kg-day)} = \frac{CS \times SIR \times FI}{BW \times CF}$$

Where:

CS	=	Chemical concentration in surface soil (mg/kg)
SIR	=	Soil ingestion rate (g dry weight/day)
FI	=	Fraction ingested from contaminated source (unitless)
BW	=	Body weight (kg)
CF	=	Conversion factor (g/kg)
Exposure Assumptions		
CS	=	Surface soil concentrations (mg/kg) are presented in Table 2-1.
SIR	=	1.7 g dry weight/day[a]
FI	=	1[b]
BW	=	0.077 kg (Dunning, 1984)
CF	=	1000 g/kg

[a]Assumed to be 10.4% of food intake (EPA, 1993).
[b]Assumes home range of the robin falls within the site area.

on earthworms, is approximately 10.4%. EPA (1993) further suggests that other species that ingest earthworms might be expected to have similar soil intakes. A best estimate of 10.4% of the dry weight dietary ingestion rate was used for the robin's incidental soil ingestion rate. A soil ingestion rate of 1.7 g dry weight/day was assumed for the robin based on a dietary intake of 16 g dry weight/day.

Total Exposure to the American Robin

Based on the previous discussion, the total exposure of the robin to chemicals from the site was derived as follows:

$$Dose_{Total} = Dose_{worm} + Dose_{soil}$$

Where:

$Dose_{Total}$	=	Total dose (mg/kg-day).
$Dose_{worm}$	=	Dose from ingestion of earthworms (mg/kg-day).
$Dose_{soil}$	=	Dose from soil ingestion (mg/kg-day).

The total and route-specific exposure doses estimated for the robin are presented in Table 3-11.

3.4.4 Song Sparrow

The primary routes of potential on-site exposure that were evaluated for the song sparrow include the ingestion of plant material and the incidental ingestion of soil. The methodology used to calculate the exposure doses for the sparrow and the associated assumptions are presented in the following paragraphs.

Table 3-11

Exposure Doses Estimated for the American Robin (mg/kg-day)

Chemical	Soil Ingestion Dose		Earthworm Ingestion Dose		Total Dose	
	Mean	95% UCL	Mean	95% UCL	Mean	95% UCL
Organics						
Chlordane	3.69E−02	1.25E−01	1.74E+00	5.86E+00	1.77E+00	5.98E+00
DDD	5.32E−03	1.81E−02	4.16E−01	1.41E+00	4.21E−01	1.43E+00
DDE	1.24E−02	5.67E−02	8.63E−01	3.95E+00	8.75E−01	4.01E+00
DDT	1.77E−02	1.02E−01	1.76E+00	1.02E+01	1.78E+00	1.03E+01
Dieldrin	7.57E−04	2.13E−03	7.06E−02	1.99E−01	7.13E−02	2.01E−01
Endrin	5.96E−03	1.10E−02	2.02E−01	3.74E−01	2.08E−01	3.85E−01
PAHs (total)	5.04E−01	1.24E+00	1.56E+00	3.86E+00	2.07E+00	5.10E+00
Benzo(a)anthracene	5.14E−02	1.73E−01	1.31E−01	4.39E−01	1.82E−01	6.12E−01
Benzo(a)pyrene	5.78E−02	8.01E−02	1.85E−01	2.56E−01	2.43E−01	3.37E−01
Benzo(b)fluoranthene	3.80E−02	8.70E−02	7.51E−02	1.72E−01	1.13E−01	2.59E−01
Benzo(g,h,i)perylene	3.38E−02	9.80E−02	4.77E−02	1.38E−01	8.15E−02	2.36E−01
Benzo(k)fluoranthene	5.08E−02	1.34E−01	1.00E−01	2.64E−01	1.51E−01	3.98E−01
Chrysene	5.21E−02	2.89E−01	2.16E−01	1.20E+00	2.68E−01	1.49E+00
Dibenz(a,h)anthracene	8.28E−03	1.03E−02	3.82E−02	4.73E−02	4.65E−02	5.76E−02
Fluoranthene	7.88E−02	1.23E−01	2.74E−01	4.27E−01	3.53E−01	5.49E−01
Indeno(1,2,3−cd)pyrene	4.13E−02	9.03E−02	1.59E−01	3.48E−01	2.01E−01	4.39E−01
Pyrene	9.21E−02	1.55E−01	3.38E−01	5.68E−01	4.30E−01	7.23E−01
PCB (Aroclor 1260)	6.95E−03	1.10E−02	1.44E+00	2.27E+00	1.45E+00	2.28E+00
Inorganics						
Arsenic	3.07E−01	3.73E−01	1.39E−01	1.69E−01	4.46E−01	5.42E−01
Cadmium	1.53E−02	1.79E−02	6.61E−01	7.73E−01	6.77E−01	7.91E−01
Chromium	5.30E−01	5.92E−01	3.84E+00	4.29E+00	4.37E+00	4.88E+00
Copper	2.21E+00	2.23E+00	9.14E+00	9.23E+00	1.14E+01	1.15E+01
Lead	4.70E+00	6.42E+00	2.35E+01	3.20E+01	2.82E+01	3.85E+01
Manganese	8.61E+00	9.74E+00	8.91E+00	1.01E+01	1.75E+01	1.98E+01
Nickel	6.31E−01	7.46E−01	1.07E+01	1.26E+01	1.13E+01	1.34E+01
Zinc	3.05E+00	3.47E+00	2.84E+02	3.23E+02	2.87E+02	3.26E+02

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Ingestion of Plant Seeds

Seeds of grasses and weeds consist of approximately 75% of the song sparrow's yearly diet; and up to 92% of the sparrow's fall diet. Insects and other invertebrates comprise the remainder of the sparrow's diet (Martin et al., 1961). Although a bird's diet can vary with season and availability of resources, for this assessment it was assumed that the sparrow's diet consists entirely of plant seeds.

The exposure doses to the sparrow through the ingestion of plant seeds were determined using the approach and assumptions presented in Table 3-12. In a study by Nagy (1987), approximately 10 species of passerine birds were studied for correlation between individual metabolic rates and body weights. Some of the species of passerines studied by Nagy had body weights and foraging habits similar to the song sparrow's. To determine an appropriate ingestion rate for the sparrow, the following model from Nagy (1987) was used to represent the relationship between field metabolic rate and body weight:

$$FMR = 2.123 * BW^{0.749}$$

Where:

FMR = Field metabolic rate (kcal/day)

BW = Body weight (g)

Placing the average male and female song sparrow body weight of 20.8 grams (Dunning, 1984) in this model results in a field metabolic rate of approximately 20.6 kcal/day. This is very similar to an 85 kjoules/day (*i.e.*, 20.3 kcal/day) energy requirement, as reported in the literature for the chipping sparrow (Pulliam, 1985). Assuming that the usable energy in seeds is 16 joules/mg (3.8 kcal/g) (Pulliam, 1985), a dry weight ingestion rate of 5.4 g/day was estimated for the song sparrow (*i.e.*, 20.6 kcal/day ÷ 3.8 kcal/g). The methods for calculating the chemical concentrations in seeds is presented in Appendix C.

The fraction of the sparrow's dietary intake that it ingests from a particular site is dependent on the size of its home range in relation to the size of the site. Because the sparrow's home

Table 3-12

Model for Calculating Doses to the Song Sparrow Through the Ingestion of Plant Seeds

$$\text{Seed Ingestion Dose (mg/kg-day)} = \frac{CS \times SIR \times FI}{BW \times CF}$$

Where:

CS	=	Chemical concentration in seeds (mg/kg dry weight)
SIR	=	Seed ingestion rate (g dry weight/day)
FI	=	Fraction ingested from contaminated source (unitless)
BW	=	Body weight (kg)
CF	=	Conversion factor (g/kg)

Exposure Assumptions

CS	=	Seed concentrations (mg/kg) are presented in Table C-2 (Appendix C).
SIR	=	5.4 g dry weight/day (Nagy, 1987; Pulliam, 1985)
FI	=	1[a]
BW	=	0.0208 kg (Dunning, 1984)
CF	=	1000 g/kg

[a]Assumes home range of the sparrow falls within the site area.

range of 0.5 to 1.5 acres (DeGraaf and Rudis, 1986) is less than the total area of the site, 100% of the sparrow's foraging is assumed to occur at the site.

Incidental Ingestion of Soil

The song sparrow may also be exposed to chemicals through incidental soil ingestion. Birds inadvertently ingest soil while ground foraging, preening, and nesting. The exposure doses to the song sparrow through the incidental ingestion of soil were determined using the approach and assumptions presented in Table 3-13.

Young and Cockerham (1985) reported relatively higher liver concentrations of TCDD for Southern meadowlarks residing around a TCDD-contaminated site at Eglin Air Force Base, Florida. They hypothesized that the Southern meadowlark ingested soil while preening and foraging for soil-borne insects. Based on this report, it was assumed that the song sparrow's soil intake is between 0.1 and 10% of its dietary intake. A best estimate of 1% of the dry weight dietary ingestion rate was used for the sparrow's incidental soil ingestion rate, based on a similar assumption made by EPA for the Eastern meadowlark (EPA, 1990a). A dry weight soil ingestion rate of 0.054 g/day was calculated for the song sparrow based on 1% of the sparrow's dietary intake of 5.4 g/day.

Total Exposure to the Song Sparrow

Based on the previous discussion, the total exposure of the song sparrow to chemicals from the site was derived as follows:

$$Dose_{Total} = Dose_{plant} + Dose_{soil}$$

Where:

$Dose_{Total}$	=	Total dose (mg/kg-day).
$Dose_{plant}$	=	Dose from ingestion of plant seeds (mg/kg-day).
$Dose_{soil}$	=	Dose from soil ingestion (mg/kg-day).

Table 3-13

Model for Calculating Doses to the Song Sparrow Through the Incidental Ingestion of Soil

$$\underset{(\text{mg/kg-day})}{\text{Soil Ingestion Dose}} = \frac{CS \times SIR \times FI}{BW \times CF}$$

Where:

CS	=	Chemical concentration in surface soil (mg/kg)
SIR	=	Soil ingestion rate (g dry weight/day)
FI	=	Fraction ingested from contaminated source (unitless)
BW	=	Body weight (kg)
CF	=	Conversion factor (g/kg)

Exposure Assumptions

CS	=	Surface soil concentrations are presented in Table 2-1.
SIR	=	0.054 g dry weight/day[a]
FI	=	1[b]
BW	=	0.0208 kg (Dunning, 1984)
CF	=	1000 g/kg

[a]Assumed to be 1% of food intake (EPA, 1990).
[b]Assumes home range of the sparrow falls within the site area.

The total and route-specific exposure doses estimated for the song sparrow are presented in Table 3-14.

4.0 ECOLOGICAL EFFECTS CHARACTERIZATION

In the ecological effects characterization, information on the toxicity of the chemicals of potential concern to ecological receptors is presented. The toxicity information is used in the development of reference toxicity values (RTVs) (*i.e.*, acceptable daily doses or media concentrations) for selected indicator species. A comprehensive literature and database search was performed to identify relevant toxicological data for the receptors. The data sources that were reviewed included:

- Toxline.
- Registry of Toxic Effects of Chemical Substances (RTECS).
- Chemical Abstracts (CA Service).
- Integrated Risk Information System (IRIS).
- Hazardous Substances Data Base (HSDB).
- Phytotox.

In addition to these databases, toxicity information was obtained from a variety of primary literature sources as presented throughout the following subsections.

Species-specific toxicity data for indicator wildlife species often were not available for the chemicals of potential concern. Thus, where possible, toxicity values from the literature were selected using the most closely related species. Data for chronic toxicity were preferentially used, when available. Toxicity values selected for the assessment were the lowest exposure doses reported to be toxic or the highest doses associated with no adverse effect. If a dose reported to be toxic was used as the basis of the RTV, it was extrapolated to a no effect dose. Also, toxicity data reported as parts per million (ppm) in the diet were converted to a mg/kg body weight/day intake using data presented in the study, where available, or information on average ingestion rates and body weights of test animals. In addition, when toxicity data were not available for a specific substance, toxicity data from related isomers were used.

Table 3-14

Exposure Doses Estimated for the Song Sparrow (mg/kg-day)

Chemical	Soil Ingestion Dose		Seed Ingestion Dose		Total Dose	
	Mean	95% UCL	Mean	95% UCL	Mean	95% UCL
Organics						
Chlordane	4.34E-03	1.46E-02	4.15E-01	1.40E+00	4.19E-01	1.42E+00
DDD	6.26E-04	2.13E-03	8.38E-04	2.85E-03	1.46E-03	4.98E-03
DDE	1.46E-03	6.67E-03	3.15E-03	1.44E-02	4.60E-03	2.11E-02
DDT	2.08E-03	1.20E-02	1.20E-02	6.91E-02	1.41E-02	8.10E-02
Dieldrin	8.90E-05	2.51E-04	3.10E-03	8.74E-03	3.19E-03	8.99E-03
Endrin	7.01E-04	1.30E-03	2.44E-02	4.52E-02	2.51E-02	4.65E-02
PAHs (total)	5.93E-02	1.46E-01	2.83E-01	5.24E-01	3.43E-01	6.69E-01
Benzo(a)anthracene	6.05E-03	2.03E-02	1.34E-02	4.49E-02	1.94E-02	6.53E-02
Benzo(a)pyrene	6.80E-03	9.42E-03	1.20E-01	1.67E-01	1.27E-01	1.76E-01
Benzo(b)fluoranthene	4.47E-03	1.02E-02	5.45E-03	1.25E-02	9.91E-03	2.27E-02
Benzo(g,h,i)perylene	3.97E-03	1.15E-02	2.65E-03	7.70E-03	6.63E-03	1.92E-02
Benzo(k)fluoranthene	5.97E-03	1.57E-02	7.28E-03	1.92E-02	1.33E-02	3.49E-02
Chrysene	6.13E-03	3.40E-02	1.35E-02	7.52E-02	1.97E-02	1.09E-01
Dibenz(a,h)anthracene	9.74E-04	1.21E-03	1.33E-03	1.65E-03	2.31E-03	2.86E-03
Fluoranthene	9.27E-03	1.44E-02	5.28E-02	8.21E-02	6.21E-02	9.65E-02
Indeno(1,2,3-cd)pyrene	4.85E-03	1.06E-02	3.24E-03	7.09E-03	8.10E-03	1.77E-02
Pyrene	1.08E-02	1.82E-02	6.33E-02	1.06E-01	7.42E-02	1.25E-01
PCB (Aroclor 1260)	8.18E-04	1.29E-03	9.32E-04	1.47E-03	1.75E-03	2.76E-03
Inorganics						
Arsenic	3.61E-02	4.39E-02	2.17E-02	2.63E-02	5.77E-02	7.02E-02
Cadmium	1.80E-03	2.10E-03	2.69E-02	3.15E-02	2.87E-02	3.36E-02
Chromium	6.23E-02	6.96E-02	2.80E-02	3.13E-02	9.03E-02	1.01E-01
Copper	2.60E-01	2.62E-01	6.49E+00	6.56E+00	6.75E+00	6.82E+00
Lead	5.53E-01	7.55E-01	4.98E-01	6.80E-01	1.05E+00	1.44E+00
Manganese	1.01E+00	1.14E+00	5.06E+00	5.72E+00	6.08E+00	6.87E+00
Nickel	7.43E-02	8.77E-02	4.46E-01	5.27E-01	5.20E-01	6.14E-01
Zinc	3.58E-01	4.08E-01	3.22E+01	3.67E+01	3.26E+01	3.71E+01

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4.1 Toxicity to Terrestrial Wildlife

Since toxicity data for terrestrial wildlife are not nearly as complete as that found for laboratory and aquatic species, extrapolation of toxicity data from other animal studies is often necessary. Because of the uncertainty associated with these extrapolations, safety factors are applied to toxicological data to derive RTVs. The approach taken to derive RTVs for this study is provided in Table 4-1.

For those chemicals for which only acute lethality values were available, toxicity values for this assessment were derived by dividing the acute toxicity value by the appropriate safety factors. Based upon the guidance provided by the EPA (1986), a median lethal dose (LD_{50}) may be extrapolated to an acute toxicity threshold by dividing the LD_{50} by a safety factor of 5. This safety factor is based on an analysis of dose-response data for pesticides. A dose-response 5 times lower than the LD_{50} would be expected to result in a mortality rate of about 0.1% under typical conditions, and up to 10% when the responses in the test population are highly variable. Protection of 90 to 99% of a population is expected to provide an adequate margin of safety. Acute values were not extrapolated to chronic values.

A safety factor of 5 was applied in the extrapolation of a chronic lowest-observable-adverse-effect-level (LOAEL) to a chronic no-observable-adverse-effect-level (NOAEL). Weil and McCollister (1963) examined ratios of LOAELs to NOAELs from chronic and subchronic studies. Their analysis showed that 96% (50 out of 52) of the ratios were less than or equal to 5 (Lewis et al., 1990).

A safety factor of 5 was also applied when the test species differed from the indicator species selected for the site, since animal species can exhibit differences in sensitivity to a chemical (EPA, 1991b). Chemical-specific toxicity data for the indicator species were not found in the literature. Rather, short-tailed shrew and white-footed mouse RTVs for the constituents of concern were extrapolated from other mammalian studies, and robin and song sparrow RTVs were extrapolated from other avian studies, preferably using data from species with similar diets and digestive systems. Most of the available RTVs are based on

Table 4-1

Safety Factors Used to Derive Reference Toxicity Values for Terrestrial Target Organisms

Available Toxicity Endpoint	Target Toxicity Endpoint	Safety Factor
Acute Lethality (i.e., LD_{50})	Acute Toxicity Threshold	5
Chronic LOAEL	Chronic NOAEL	5
Within Phylogenetic Class Sensitivity (i.e., different species but same class)	Target Species Toxicity	5

For example, in developing a reference toxicity value for a short-tailed shrew when the only data available is a chronic LOAEL for a rat, the following steps would be taken:

Rat chronic LOAEL for Compound X = 500 mg/kg.

(1) Chronic LOAEL → Chronic NOAEL $\frac{500 \text{ mg/kg}}{5} = 100$ mg/kg

(2) Within Phylogenetic Class → Target Species RTV $\frac{100 \text{ mg/kg}}{5} = 20$ mg/kg

effects in common laboratory species (*e.g.*, rats, mice, quail).

Using this methodology, the estimated RTVs for the Northern short-tailed shrew and the white-footed mouse are the same, and the estimated RTVs for the robin and song sparrow are the same. The RTVs for the mammalian and avian species are presented in Tables 4-2 and 4-3, respectively, along with the toxicity data used to calculate the RTVs.

4.2 Toxicity to Terrestrial Vegetation

There is currently no EPA guidance for quantitatively evaluating potential adverse effects to plants growing in contaminated soils. For this assessment, the phytotoxic potential of site-related chemicals was evaluated by comparing soil concentrations at the site to growth medium concentrations reported in the literature to cause adverse effects in plants Soil concentrations that did not result in any toxic effects in plants were also used as a basis of comparison, when available. Plant toxicity data are presented in Table 4-4.

4.3 Toxicity to Soil Invertebrates

There is currently no EPA guidance for quantitatively evaluating potential adverse effects to soil invertebrates inhabiting contaminated soils. For this assessment, potential toxicity to soil invertebrates from exposure to site-related chemicals was evaluated by comparing the site-specific soil concentrations to the soil concentrations reported in the literature to cause adverse effects to soil invertebrates. Soil invertebrate toxicity data are presented in Table 4-5.

Table 4-2

Basis of the Mammalian Reference Toxicity Values (RTVs) (mg/kg-day)

Chemical	Species	Toxicity Endpoint	Effect	Dose (mg/kg-day)	Reference	Applied Safety Factor	Mammalian RTVs (mg/kg-day)
Organics							
Chlordane	Mouse	Chronic NOAEL	No significant liver lesions	6.50E-01	Khasawinah and Grutsch, 1989	5	1.3E-01
DDD	Rat	Chronic Effect Dose	Decreased organ/body weight;suppressed immunity	1.21E+02	Hamid et al., 1974	25	4.8E+00
DDE	Rat	Chronic Effect Dose	Mortality associated with tumor growth	2.19E+01	NCI, 1978	25	8.8E-01
DDT	Rat	Chronic NOAEL	No growth effect on pups	1.00E+00	Clement and Okey, 1974	5	2.0E-01
Endrin	Rat	Chronic NOAEL	No significant mortality	2.50E-01	Treon et al., 1955	5	5.0E-02
PAHs[a]	Mouse	Chronic No Effect Dose	No effect on reproduction/fertility	1.30E+02	Rigdon and Neal, 1965	5	2.6E+01
PCBs (Aroclor 1260)	Rat	Chronic NOAEL	No reproductive effect	6.90E+00	Linder et al., 1974	5	1.4E+00
Inorganics							
Arsenic	Mouse	Chronic Effect Dose	Decreased survival in males	9.50E-01	Schroeder and Balassa, 1967	25	3.8E-02
Cadmium	Rat	Chronic NOAEL	No effect on motor or kidney function	1.64E+00	Kotsonis and Klaassen, 1978	5	3.3E-01

Table 4-2 (cont'd.)

Basis of the Mammalian Reference Toxicity Values (RTVs) (mg/kg-day)

Chemical	Species	Toxicity Endpoint	Effect	Dose (mg/kg-day)	Reference	Applied Safety Factor	Mammalian RTVs (mg/kg-day)
Chromium	Mouse	Chronic Effect Dose	Decreased spermatogenesis	4.57E+00	Zahid et al., 1990	25	1.8E-01
Copper	Mouse	Chronic NOAEL	No reproductive effects	2.60E+02	Lecyk, 1980	5	5.2E+01
Lead	Rat	Chronic NOAEL	No depressed immunity	4.60E+00	Luster et al., 1978	5	9.2E-01
Manganese	Rat	Chronic Effect Dose	Motor ability, aggressive behavior	1.40E+02	Chandra, 1983	25	5.6E+00
Nickel	Rat	Chronic Effect Dose	Increased number of young deaths and runts	7.00E-01	Schroeder and Mitchener, 1971	25	2.8E-02
Zinc	Rat	Chronic NOAEL	No reproductive effects	1.00E+02	Schlicker and Cox, 1968	5	2.0E+01

NOAEL - No-observable-adverse-effect-level.
[a]This data is based on benzo(a)pyrene. The RTV for benzo(a)pyrene was applied to all PAHs.

Table 4-3

Basis of the Avian Reference Toxicity Values (RTVs) (mg/kg-day)

Chemical	Species	Toxicity Endpoint	Effect	Dose (mg/kg-day)	Reference	Applied Safety Factor	Avian RTV (mg/kg-day)
Organics							
Chlordane	Bobwhite (chick)	Acute LC_{50}	50% mortality	5.20E+01	Heath et al., 1972	25	2.1E+00
DDD	Ring-necked pheasant	Acute LC_{50}	50% mortality	5.90E+01	Hill et al., 1975	25	2.4E+00
DDE	Black duck	Chronic Effect Dose	Eggshell thinning and cracking, decreased duckling survival	5.60E-01	Longcore et al., 1971	25	2.2E-02
DDT	Mallard (adult)	Chronic NOAEL	No eggshell thinning	1.85E-01	Davison and Sell, 1974	5	3.7E-02
Endrin	Mallard	Chronic NOAEL	No reproductive effects	1.20E-01	Heath et al., 1972	5	2.4E-02
PAHs	NDA						
PCBs (Aroclor 1260)	Bobwhite (chick)	Acute LC_{50}	50% mortality	1.17E+02	Heath et al., 1972	25	4.7E+00
Inorganics							
Arsenic	Mallard (1-day old)	Chronic NOAEL	No significant behavioral effects	2.89E+01	Whitworth et al., 1991	5	5.8E+00

Table 4-3 (cont'd.)

Basis of the Avian Reference Toxicity Values (RTVs) (mg/kg-day)

Chemical	Species	Toxicity Endpoint	Effect	Dose (mg/kg-day)	Reference	Applied Safety Factor	Avian RTV (mg/kg-day)
Cadmium	Mallard	Chronic LOAEL	Egg production suppression	2.00E+01	White and Finley, 1978	25	8.0E-01
Chromium	Chicks (3-week old)	Chronic NOAEL	No effects on body weight or mortality	9.52E+01	Hill and Matrone, 1970	5	1.9E+01
Copper	Chicks (1-day old)	Chronic NOAEL	No significant mortality	5.60E+01	Mehring et al., 1960	5	1.1E+01
Lead	Japanese quail (chicks)	Chronic NOAEL	No anemia, no depressed growth	2.60E+01	Morgan et al., 1975	5	5.2E+00
Manganese	Turkey poults	Acute NOAEL	No deleterious effects	2.29E+02	Vohra and Kratzer, 1968	5	4.6E+01
Nickel	Chicks (1-day old)	Acute NOAEL	No depressed weight gain	1.69E+01	Weber and Reid, 1968	5	3.4E+00
Zinc	Chicks (1-day old)	Chronic NOAEL	No effects	2.53E+02	Oh et al., 1979	5	5.1E+01

NDA - No Data Available
NOAEL - No-observable-adverse-effect-level
LOAEL - Lowest-observable-adverse-effect-level

Table 4-4

Phytotoxicity Values for the Chemicals of Potential Concern

Chemical	Plant Species	Treatment Duration	Media	Concentration (mg/kg)	Effects Measured	References	Comments
ORGANICS							
CHLORDANE (TOTAL)	grass	1 month	growth medium	32.5	95% decrease in germination	Phytotox Database (Juska, FV, 1961)	secondary source; converted from units of lb/acre
4,4'-DDD	NDA						
4,4'-DDE	NDA						
4,4'-DDT	bean	not given	growth medium	38.5	no injury to shoots, incr. in # of roots	Phytotox Database (Fults & Payne, 1947)	secondary source; converted from units of lb/acre
4,4'-DDT	chrysanthemum	not given	aqueous sol.	2000 mg/L	no effect on plant	Phytotox Database (Dennis, EB., 1963)	secondary source, mature roots soaked
DIELDRIN	eggplant/cabbage	35 days	growth medium	0.31	shoot mass increase, root mass decrease	Phytotox Database (Kabir & Khan, 1972)	secondary source; converted from units of lb/acre
DIELDRIN	corn	2 weeks	growth medium	1.149	plant size decrease	Phytotox Database (Cole et al., 1976)	secondary source; converted from units of lb/acre
DIELDRIN	cotton	1-5 hours	aqueous sol.	2,000 mg/L	decreased germination (77%) and growth	Eid et al., 1971	lowest of 3 conc. tested (LEC), seeds were soaked
DIELDRIN	cotton	1-5 hours	aqueous sol.	10,000 mg/L	98% avg decrease in germination	Eid et al., 1971	second highest conc. tested, seeds were soaked
DIELDRIN	corn	1-5 hour	aqueous sol.	2,000 mg/L	14% avg decrease in seed germination	Eid et al., 1971	lowest of 3 conc. tested, seeds were soaked
DIELDRIN	corn	1-5 hour	aqueous sol.	10,000 mg/L	64% decrease in seed germination	Eid et al., 1971	second highest conc. tested, seeds were soaked
ENDRIN	NDA						
PAHS							
BENZO(A) ANTHRACENE	NDA						
BENZO(A) PYRENE	NDA						
BENZO(B) FLUORANTHENE	NDA						
BENZO(G,H,I) PERYLENE	NDA						
BENZO(K) FLUORANTHENE	NDA						
CHRYSENE	NDA						
DIBENZO(A,H) ANTHRACENE	NDA						
FLUORANTHENE	NDA						
INDENO(1,2,3-CD) PYRENE	NDA						
PYRENE	NDA						
PCBs (Aroclor-1260)	NDA						
INORGANICS							
ARSENIC	Bermuda grass	6 weeks	clay,loam,sand	11-15	no growth reduction	Weaver et al., 1984	As_2O_3; media pH 7.6 (clay), 7.7 (loam), 4.7 (sand)
ARSENIC	Bermuda grass	6 weeks	sand, silty loam	46-50	reduced yield	Weaver et al., 1984	As_2O_3; media pH 7.7 (loam), 4.7 (sand)
ARSENIC	Bermuda grass	6 weeks	clay	49	no growth reduction	Weaver et al., 1984	As_2O_3; media pH 7.6
ARSENIC	Bermuda grass	6 weeks	sand, silty loam	91-95	prevented growth	Weaver et al., 1984	As_2O_3; media pH 7.7 (loam), 4.7 (sand)
ARSENIC	Bermuda grass	6 weeks	clay	94	reduced growth	Weaver et al., 1984	As_2O_3; media pH 7.6
ARSENIC	grass	not given	soil	104	crop yield 88% of control	Sheppard, 1992	species of arsenic unknown, secondary source
ARSENIC	grass	not given	soil	320	crop very stunted	Sheppard, 1992	species of arsenic unknown, secondary source
ARSENIC	oat	not given	sand, silty loam	1000	100% Y.R. in shoots	EPA, 1987a (Woolson et al., 1973)	secondary source, media pH 5.5
ARSENIC	corn	not given	silty clay loam	1000	90% Y.R. in shoots	EPA, 1987a (Woolson et al., 1973)	secondary source, media pH 5.5
ARSENIC	oat	not given	silty clay loam	100	81% Y.R. in shoots	EPA, 1987a (Woolson et al., 1973)	secondary source, media pH 5.5
ARSENIC	corn	not given	silty clay loam	100	4% Y.R. in shoots	EPA, 1987a (Woolson et al., 1973)	secondary source, media pH 5.5
ARSENIC	oat	not given	silty clay loam	10	22% Y.R. in shoots	EPA, 1987a (Woolson et al., 1973)	secondary source, media pH 5.5
ARSENIC	corn	not given	loamy sand	10	6% Y.R. in shoots	EPA, 1987a (Woolson et al., 1973)	secondary source, media pH 6.2
ARSENIC	pea	not given	sand	100	91.9% Y.R. in seeds	EPA, 1987a (Steevens et al., 1972)	secondary source, media pH 5.5
ARSENIC	pea	not given	sand	45	39.9% Y.R. in seeds	EPA, 1987a (Steevens et al., 1972)	secondary source, media pH 5.5
ARSENIC	pea	not given	sand	27	2.8% yield increase in seeds	EPA, 1987a (Steevens et al., 1972)	secondary source, media pH 5.5
ARSENIC	not specified	not given	surface soil	50	"tolerable amount"	El-Bassam and Tietjen, 1977	proposed amount
ARSENIC	not specified	not given	surface soil	25	"phytotoxically excessive"	Kabata.., 1984 (Linzon, 1978)	secondary source
ARSENIC	not specified	not given	surface soil	30	"phytotoxically excessive"	Kabata..., 1984 (Pendias, 1979)	secondary source
ARSENIC	not specified	not given	surface soil	20	"phytotoxically excessive"	Kabata.., 1984 (Kloke, 1981)	secondary source

Table 4–4 (cont'd.)

Phytotoxicity Values for the Chemicals of Potential Concern

Chemical	Plant Species	Treatment Duration	Media	Concentration (mg/kg)	Effects Measured	References	Comments
ARSENIC	not specified	not given	surface soil	15	"phytotoxically excessive"	Kabata.., 1984 (Kitagishi..., 1979)	secondary source
CADMIUM	soybean	not given	soil	2.5	growth retardation and leaf discoloration	Hammons et al., 1978	represents min. conc, secondary source
CADMIUM	winter wheat	not given	soil	2.5	general growth retardation	Hammons et al., 1978	represents min. conc, secondary source
CADMIUM	lettuce	not given	soil	2.5	general growth retardation	Hammons et al., 1978	represents min. conc, secondary source
CADMIUM	pea	95 days	soil	40	decrease in seed yield	Hammons et al., 1978	lowest conc. tested (LEC), secondary source
CADMIUM	pea	95 days	soil	200	decrease in pod, vine, and root yield	Hammons et al., 1978	highest conc. tested, secondary source
CADMIUM	oat	100 days	soil	40	decrease in grain yield	Hammons et al., 1978	lowest conc. tested (LEC), secondary source
CADMIUM	lettuce	35 days	soil	200	decrease in leaf yield	Hammons et al., 1978	highest conc. tested, secondary source
CADMIUM	fern	not given	grwth medium	2.7	decrease in spore germination	Gupta and Devi, 1992	EC50, *Pteris vittata*
CADMIUM	fern	not given	grwth medium	1.7	decrease in spore germination	Gupta and Devi, 1992	EC50, *Adiantum lunulatum*
CADMIUM	fern	not given	grwth medium	2.8	decrease in spore germination	Gupta and Devi, 1992	EC50, *Ampelopteris prolifera*
CADMIUM	alfalfa	not given	fine sndy loam	250	21% to 72% Y.R. in tops	EPA, 1987a (Taylor & Allinson, 1981)	secondary source, media pH 6.9
CADMIUM	alfalfa	not given	fine sndy loam	125	0.7% to 56% yield increase in tops	EPA, 1987a (Taylor & Allinson, 1981)	secondary source, media pH 6.9
CADMIUM	alfalfa	not given	fine sndy loam	50	3.5% to 9.8% yield increase in tops	EPA, 1987a (Taylor & Allinson, 1981)	secondary source, media pH 6.9
CADMIUM	5 species	not given	silt loam	200	10 to 98.5% Y.R. in leaves	EPA, 1987a (John, 1973)	secondary source, media pH 5.1; grains/veg.
CADMIUM	5 species	not given	silt loam	40	0 to 96% Y.R. in leaves	EPA, 1987a (John, 1973)	secondary source, media pH 5.1; grains/veg.
CADMIUM	7 species	not given	sand	30	10 to 90% Y.R. in shoots	EPA, 1987a (Miles & Parker, 1979)	secondary source, media pH 4.8;wildflwrs/grasses
CADMIUM	7 species	not given	sand	10	24% Y.I. to 78% Y.R. in shoots	EPA, 1987a (Miles & Parker, 1979)	secondary source, media pH 4.8;wildflwrs/grasses
CADMIUM	alfalfa	not given	sandy loam	5	20% yield increase in tops	EPA, 1987a (Taylor & Allinson, 1981)	secondary source, media pH 6.9
CADMIUM	alfalfa	not given	sandy loam	5	16% Y.R. in shoots	EPA, 1987a (Taylor & Allinson, 1981)	secondary source, media pH 6.9
CADMIUM	alfalfa	not given	sandy loam	5	13.6% Y.R. in shoots	EPA, 1987a (Taylor & Allinson, 1981)	secondary source, media pH 6.9
CADMIUM	not specified	not given	surface soil	5	"tolerable amount"	El–Bassam and Tietjen, 1977	proposed amount, with "special reservation"
CADMIUM	not specified	not given	surface soil	8	"phytotoxically excessive"	Kabata.., 1984 (Linzon, 1978)	secondary source
CADMIUM	not specified	not given	surface soil	5	"phytotoxically excessive"	Kabata.., 1984 (Pendias, 1979)	secondary source
CADMIUM	not specified	not given	surface soil	3	"phytotoxically excessive"	Kabata.., 1984 (Kloke, 1981)	secondary source
CHROMIUM	not specified	not given	surface soil	100	"tolerable amount"	El–Bassam and Tietjen, 1977	proposed amount
CHROMIUM	not specified	not given	surface soil	75	"phytotoxically excessive"	Kabata.., 1984 (Linzon, 1978)	secondary source
CHROMIUM	not specified	not given	surface soil	100	"phytotoxically excessive"	Kabata.., 1984 (Pendias, 1979)	secondary source
CHROMIUM	not specified	not given	surface soil	100	"phytotoxically excessive"	Kabata.., 1984 (Kloke, 1981)	secondary source
COPPER	bush bean	17 days	yolo loam	500	83% Y.R. in leaves, 69% Y.R. in stems	EPA, 1987b (Wallace et al., 1977a)	secondary source
COPPER	bush bean	17 days	yolo loam	200	26% Y.R. in leaves, 14% Y.R. in stems	EPA, 1987b (Wallace et al., 1977a)	secondary source
COPPER	corn	6 weeks	sandy loam	150	61% to 68% Y.R. in above ground biomass	EPA, 1987b (Cunningham et al., 1975b)	secondary source
COPPER	rye	6 weeks	sandy loam	150	43% Y.R. in above ground biomass	EPA, 1987b (Cunningham et al., 1975b)	secondary source
COPPER	white clover	not given	sandy soil	52	50% Y.R. in shoots	EPA, 1987b (Dijkshoorn et al., 1979)	secondary source
COPPER	onion	not given	sandy loam	30	16% Y.R. in leaves	EPA, 1987b (Gildon and Tinker, 1983)	secondary source
COPPER	not specified	not given	soil	100	plant growth inhibition	EPA, 1987b	secondary source
COPPER	not specified	not given	surface soil	100	"tolerable amount"	El–Bassam and Tietjen, 1977	proposed amount
COPPER	not specified	not given	surface soil	60	excessive or upper threshold conc.	Kovalsky, 1974	15–60 ppm is range of normal regulation of funct.
COPPER	not specified	not given	surface soil	100	"phytotoxically excessive"	Kabata.., 1984 (Linzon, 1978)	secondary source
COPPER	not specified	not given	surface soil	100	"phytotoxically excessive"	Kabata.., 1984 (Pendias, 1979)	secondary source
COPPER	not specified	not given	surface soil	100	"phytotoxically excessive"	Kabata.., 1984 (Kloke, 1981)	secondary source
COPPER	not specified	not given	surface soil	125	"phytotoxically excessive"	Kabata.., 1984 (Kitagishi..., 1979)	secondary source
LEAD	ryegrass	not given	fine sndy loam	250	no Y.R. in tops	EPA, 1987a (Allinson & Dziaco, 1981)	secondary source, media pH 4.5–6.4
LEAD	oat	not given	fine sndy loam	250	no Y.R. in seeds	EPA, 1987a (Allinson & Dziaco, 1981)	secondary source, media pH 4.5–6.4
LEAD	alfalfa	not given	fine sndy loam	250	6.7% Y.R. in tops (not significant)	EPA, 1987a (Taylor & Allinson, 1981)	secondary source, media pH 6.9
LEAD	corn	not given	sandy loam	250	41.7% Y.R. in shoots	EPA, 1987a (Miller et al., 1977)	secondary source, media pH 6.0

Table 4–4 (cont'd.)

Phytotoxicity Values for the Chemicals of Potential Concern

Chemical	Plant Species	Treatment Duration	Media	Concentration (mg/kg)	Effects Measured	References	Comments
LEAD	not specified	not given	surface soil	100	"tolerable amount"	El–Bassam and Tietjen, 1977	proposed amount
LEAD	not specified	not given	surface soil	200	"phytotoxically excessive"	Kabata.., 1984 (Linzon, 1978)	secondary source
LEAD	not specified	not given	surface soil	100	"phytotoxically excessive"	Kabata.., 1984 (Pendias, 1979)	secondary source
LEAD	not specified	not given	surface soil	100	"phytotoxically excessive"	Kabata.., 1984 (Kloke, 1981)	secondary source
LEAD	not specified	not given	surface soil	400	"phytotoxically excessive"	Kabata.., 1984 (Kitagishi..., 1979)	secondary source
MANGANESE	not specified	not given	surface soil	3000	excessive or upper threshold conc.	Kovalsky, 1974	400–3000 ppm is range of normal reg. of funct.
MANGANESE	not specified	not given	surface soil	1500	"phytotoxically excessive"	Kabata.., 1984 (Linzon, 1978)	secondary source
NICKEL	not specified	not given	surface soil	100	"tolerable amount"	El–Bassam and Tietjen, 1977	proposed amount
NICKEL	not specified	not given	surface soil	100	"phytotoxically excessive"	Kabata.., 1984 (Linzon, 1978)	secondary source
NICKEL	not specified	not given	surface soil	100	"phytotoxically excessive"	Kabata.., 1984 (Pendias, 1979)	secondary source
NICKEL	not specified	not given	surface soil	100	"phytotoxically excessive"	Kabata.., 1984 (Kloke, 1981)	secondary source
NICKEL	not specified	not given	surface soil	100	"phytotoxically excessive"	Kabata.., 1984 (Kitagishi..., 1979)	secondary source
ZINC	corn	not given	fine sndy loam	960	98.2% Y.R. in forage	EPA, 1987a (Mortvedt et al., 1975)	secondary source, media pH 5.5
ZINC	corn	not given	fine sndy loam	960	86.7% Y.R. in forage	EPA, 1987a (Mortvedt et al., 1975)	secondary source, media pH 7.0
ZINC	alfalfa	not given	silt loam	400	17% Y.R. in tops	EPA, 1987a (Boawn & Rasmussen, 1971)	secondary source, media pH 7.1
ZINC	corn	not given	fine sndy loam	240	49.1% Y.R. in forage	EPA, 1987a (Mortvedt et al., 1975)	secondary source, media pH 5.5
ZINC	corn	not given	fine sndy loam	240	5.0% Y.R. in forage	EPA, 1987a (Mortvedt et al., 1975)	secondary source, media pH 7.0
ZINC	soybean	not given	silt loam	196	0.6% to 82% Y.R. in leaves	EPA, 1987a (White & Chaney, 1980)	secondary source, media pH 5.5–6.3
ZINC	lettuce	not given	silt loam	180	no Y.R. in tops	EPA, 1987a (Mitchell et al., 1978)	secondary source, media pH 7.5
ZINC	corn	not given	fine sndy loam	60	no Y.R. in forage	EPA, 1987a (Mortvedt et al., 1975)	secondary source, media pH 5.5
ZINC	corn	not given	fine sndy loam	60	yield increase in forage	EPA, 1987a (Mortvedt et al., 1975)	secondary source, media pH 7.0
ZINC	not specified	not given	surface soil	300	"tolerable amount"	El–Bassam and Tietjen, 1977	proposed amount
ZINC	not specified	not given	surface soil	70	excessive or upper threshold conc.	Kovalsky, 1974	30–70 ppm is range of normal regulation of funct.
ZINC	not specified	not given	surface soil	400	"phytotoxically excessive"	Kabata.., 1984 (Linzon, 1978)	secondary source
ZINC	not specified	not given	surface soil	300	"phytotoxically excessive"	Kabata.., 1984 (Pendias, 1979)	secondary source
ZINC	not specified	not given	surface soil	300	"phytotoxically excessive"	Kabata.., 1984 (Kloke, 1981)	secondary source
ZINC	not specified	not given	surface soil	250	"phytotoxically excessive"	Kabata.., 1984 (Kitagishi..., 1979)	secondary source

( ) = Unavailable primary source
# = Number
conc. = Concentration
EC50 = Effect observed in 50% of organisms
funct. = functions
grwth = Growth
inc. = Increase
LEC = Lowest Effect Concentration
min. = minimum
NDA = No data available
NOEL = No Observed Effect Level
reg. = regulation
sndy = Sandy
sol. = Solution
Y.R. = Yield reduction
Y.I. = Yield increase

Table 4-5

Invertebrate Toxicity Values for the Chemicals of Potential Concern

Contaminant	Species	Concentration in Soil mg/kg (Toxicity Value)	Duration	Author(s)	Notes
Chlordane	earthworm *(Lumbricus terrestris)*	6.25 (LOEC)	21 days	Cikutovic et al. 1993	significant sperm-count depression, artificial soil mixture
DDE	earthworm *(Lumbricus terrestris)*	1.5	6 weeks	Cathey, 1982	significant changes in the epidermis shown by blisters and erythema of the clitellum; artificial soil; lowest dose tested
DDE	earthworm *(Lumbricus terrestris)*	14	6 weeks	Cathey, 1982	< 1% mortality; artificial soil
DDE	earthworm *(Lumbricus terrestris)*	61 (LC50)	6 weeks	Cathey, 1982	artificial soil
DDT	Pauropoda	30[a] (NOEC)	not listed	Edwards and Thompson, 1973	forest
DDT	Chilopoda	30[a] (NOEC)	not listed	Edwards and Thompson, 1973	forest
DDT	Diplopoda	30[a] (NOEC)	not listed	Edwards and Thompson, 1973	forest
DDT	Symphyla	30[a] (NOEC)	not listed	Edwards and Thompson, 1973	forest
DDT	Symphyla	45[a]	not listed	Edwards and Thompson, 1973	arable soils, decreased number
DDT	Pauropoda	83.4[a]	not listed	Edwards and Thompson, 1973	fallow, decreased number
DDT	Chilopoda	83.4[a]	not listed	Edwards and Thompson, 1973	fallow, decreased number
DDT	Symphyla	83.4[a]	not listed	Edwards and Thompson, 1973	fallow, decreased number
DDT	earthworm	190[a]	not listed	Edwards and Thompson, 1973	field plots, decreased number
DDT	earthworm	200[a] (NOEC)	not listed	Edwards and Thompson, 1973	forest
DDT	earthworm	450[a] (NOEC)	not listed	Edwards and Thompson, 1973	ploughed pasture

Table 4-5 (cont'd.)

Invertebrate Toxicity Values for the Chemicals of Potential Concern

Contaminant	Species	Concentration in Soil mg/kg (Toxicity Value)	Duration	Author(s)	Notes
Dieldrin	earthworm *(Eisenia fetida)*	150 (LOEC)	8 weeks	Neuhauser and Callahan, 1990	significant difference in mean final body weights
Dieldrin	earthworm *(Eisenia fetida)*	25 (LOEC)	8 weeks	Neuhauser and Callahan, 1990	significant difference in total cocoon production/worm
Dieldrin	earthworm *(Eisenia fetida)*	500 (LOEC)	8 weeks	Neuhauser and Callahan, 1990	death
Dieldrin	earthworm *(Eisenia fetida)*	30 (LOEC)	90 days	Venter and Reinecke, 1987	increased incubation periods
Dieldrin	earthworm *(Eisenia fetida)*	50 (LOEC)	90 days	Venter and Reinecke, 1987	decreased hatching success
Dieldrin	earthworm *Eisenia fetida)*	100 (LOEC)	not listed	Venter and Reinecke, 1985	delayed and retarded development of clitellum
Endrin	earthworm *(Lumbricus terrestris)*	1.5	6 weeks	Cathey, 1982	significant changes in the epidermis shown by blisters and erythema of the clitellum; artificial soil; lowest dose tested
Endrin	earthworm *(Lumbricus terrestris)*	13	6 weeks	Cathey, 1982	< 1% mortality; artificial soil
Endrin	earthworm *(Lumbricus terrestris)*	66 (LC50)	6 weeks	Cathey, 1982	artificial soil
Benzo(a)pyrene	earthworm *(Eisenia foetida)*	>26,000 (LC50)	not listed	Cureton et al., 1994	artificial soil
Cadmium	earthworm *(Eisenia foetida)*	1843 (LC50)	2 weeks	Neuhauser et al. 1986	artificial soil mixture
Cadmium	earthworm *(Eisenia foetida)*	>300 (LC50)	14 days	Spurgeon et al. 1994	
Cadmium	earthworm *(Eisenia foetida)*	>300 (LC50)	56 days	Spurgeon et al. 1994	
Cadmium	earthworm *(Eisenia foetida)*	>300 (NOEC)	56 days	Spurgeon et al. 1994	mortality
Cadmium	earthworm *(Eisenia foetida)*	46.3 (EC50)	56 days	Spurgeon et al. 1994	cocoon production

Table 4-5 (cont'd.)

Invertebrate Toxicity Values for the Chemicals of Potential Concern

Contaminant	Species	Concentration in Soil mg/kg (Toxicity Value)	Duration	Author(s)	Notes
Cadmium	earthworm *(Eisenia foetida)*	39.2 (NOEC)	56 days	Spurgeon et al. 1994	cocoon production
Cadmium	earthworm *(Eisenia andrei)*	>1000 (LC50)	3 weeks	Van Gestel and Van Straalen, 1994	artificial soil
Cadmium	earthworm *(Eisenia andrei)*	100 (NOEC)	not listed	Van Gestel and Van Straalen, 1994	body growth; artificial soil
Cadmium	earthworm *(Eisenia andrei)*	>10 (NOEC)	not listed	Van Gestel and Van Straalen, 1994	reproduction; artificial soil
Cadmium	woodlouse *(Porcellio scaber)*	100 [b]	1 year	Hopkin and Hames 1994	mortality before reproduction
Chromium	earthworm *(Eisenia andrei)*	>1000 (LC50)	3 weeks	Van Gestel and Van Straalen, 1994	artificial soil
Chromium	earthworm *(Eisenia andrei)*	320 (NOEC)	not listed	Van Gestel and Van Straalen, 1994	body growth; artificial soil
Chromium	earthworm *(Eisenia andrei)*	>32 (NOEC)	not listed	Van Gestel and Van Straalen, 1994	reproduction; artificial soil
Copper	earthworm *(Eisenia foetida)*	643 (LC50)	2 weeks	Neuhauser et al. 1986	artificial soil mixture
Copper	earthworm *(Eisenia foetida)*	683 (LC50)	14 days	Spurgeon et al. 1994	
Copper	earthworm *(Eisenia foetida)*	555 (LC50)	56 days	Spurgeon et al. 1994	
Copper	earthworm *(Eisenia foetida)*	210 (NOEC)	56 days	Spurgeon et al. 1994	mortality
Copper	earthworm *(Eisenia foetida)*	53.3 (EC50)	56 days	Spurgeon et al. 1994	cocoon production
Copper	earthworm *(Eisenia foetida)*	32 (NOEC)	56 days	Spurgeon et al. 1994	cocoon production
Copper	woodlouse *(Porcellio scaber)*	100 [b]	1 year	Hopkin and Hames 1994	mortality before reproduction

Table 4-5 (cont'd.)

Invertebrate Toxicity Values for the Chemicals of Potential Concern

Contaminant	Species	Concentration in Soil mg/kg (Toxicity Value)	Duration	Author(s)	Notes
Lead	earthworm *(Eisenia foetida)*	5941 (LC50)	2 weeks	Neuhauser et al. 1986	artificial soil mixture
Lead	earthworm *(Eisenia foetida)*	4480 (LC50)	14 days	Spurgeon et al. 1994	
Lead	earthworm *(Eisenia foetida)*	3760 (LC50)	56 days	Spurgeon et al. 1994	
Lead	earthworm *(Eisenia foetida)*	2190 (NOEC)	56 days	Spurgeon et al. 1994	mortality
Lead	earthworm *(Eisenia foetida)*	1940 (EC50)	56 days	Spurgeon et al. 1994	cocoon production
Lead	earthworm *(Eisenia foetida)*	1810 (NOEC)	56 days	Spurgeon et al. 1994	cocoon production
Lead	woodlouse *(Porcellio scaber)*	2000 [b]	1 year	Hopkin and Hames 1994	mortality before reproduction
Nickel	earthworm *(Eisenia foetida)*	757 (LC50)	2 weeks	Neuhauser et al. 1986	artificial soil mixture
Zinc	earthworm *(Eisenia foetida)*	662 (LC50)	2 weeks	Neuhauser et al. 1986	artificial soil mixture
Zinc	earthworm *(Eisenia foetida)*	1010 (LC50)	14 days	Spurgeon et al. 1994	
Zinc	earthworm *(Eisenia foetida)*	745 (LC50)	56 days	Spurgeon et al. 1994	
Zinc	earthworm *(Eisenia foetida)*	289 (NOEC)	56 days	Spurgeon et al. 1994	mortality
Zinc	earthworm *(Eisenia foetida)*	276 (EC50)	56 days	Spurgeon et al. 1994	cocoon production
Zinc	earthworm *(Eisenia foetida)*	199 (NOEC)	56 days	Spurgeon et al. 1994	cocoon production
Zinc	woodlouse *(Porcellio scaber)*	1000 [b]	1 year	Hopkin and Hames 1994	mortality before reproduction
Zinc	woodlouse *(Porcellio scaber)*	5000	not listed	Hopkin and Hames 1994	secondary source; measured in field

[a] Converted from kg/hectare assuming a bulk soil density of 1.5 g/cm^3 and a soil mixing depth for untilled soil of 1 cm (EPA, 1990b).
[b] Expressed as concentration in leaves (or food), not in soil.

5.0 RISK CHARACTERIZATION

5.1 General Approach

The potential risk posed to ecological receptors (shrew, mouse, robin, and sparrow) was assessed by comparing estimated daily doses with reference toxicity values. This comparison, described as a hazard quotient (HQ), was made for each chemical and is expressed as:

$$HQ = EDD/RTV_{ing}$$

Where:

EDD = Estimated daily dose of a chemical through a specific exposure route (*i.e.*, soil ingestion or food ingestion) (mg/kg-day).

RTV_{ing} = Reference toxicity value for the same chemical through the ingestion route (mg/kg-day).

It is important to note that this methodology is not a measure of and cannot be used to determine quantitative risk, *i.e.*, it does not predict the relative likelihood of adverse effects occurring. If the calculated hazard quotient (HQ) exceeds unity (*i.e.*, >1), then it simply indicates that the species of concern may be at risk to an adverse effect from the particular chemical or exposure route on which the HQ was calculated. Because reference toxicity values incorporate a number of safety factors, if a reference toxicity value is exceeded, *i.e.*, the hazard quotient exceeds unity, it does not necessarily indicate that an adverse effect will occur.

Exposures to the same chemical through multiple exposure routes are assumed to be cumulative. Consequently, a hazard index for a specific chemical (HI_{chem}) examines the potential for risk posed by a chemical through more than one exposure route, where applicable. For example, the cumulative hazard index for an individual chemical in all media was determined for the shrew as follows:

$$HI_{chem} = HQ_{worm} + HQ_{soil}$$

Where:

HI_{chem}	=	Hazard index for a chemical.
HQ_{worm}	=	Hazard quotient for the same chemical through ingestion of earthworms.
HQ_{soil}	=	Hazard quotient for the same chemical through soil ingestion.

As with the hazard quotient, a chemical-specific hazard index greater than 1 does not necessarily indicate that an adverse effect will occur.

To assess the potential for adverse effects to occur to plants, soil chemical data was compared to phytotoxicity data available in the literature. Since phytotoxicity data is often not species-specific, or is available for plant species that are not present at the site, an HQ was not calculated. Rather, the phytotoxicity data, which were available for a variety of plant species, were compared to the soil chemical data.

Similarly, an HQ was not calculated for soil invertebrates. Since there is not a large toxicological database for invertebrates, available data are presented, and are directly compared to the soil chemical data.

The following is a discussion of the potential risks posed to terrestrial wildlife, plant life, and soil invertebrates for the chemicals of potential concern. The risk is specific to the previously presented exposure scenarios. Uncertainties associated with these risk estimates are discussed in Section 6.

5.2 Risk Characterization for Terrestrial Wildlife

5.2.1 Northern Short-Tailed Shrew

Potential risk to the short-tailed shrew was estimated by comparing the estimated daily doses for the chemicals of potential concern (Table 3-5) with the reference toxicity values derived for the shrew (Table 4-2). The resulting hazard indices for the shrew are presented in Table 5-1. Hazard indices were calculated based on the arithmetic mean of the soil concentrations as well as the upper 95% confidence limit of the mean.

As shown in Table 5-1, the following chemicals exceeded a hazard index of one:

Mean

- Chlordane (12)
- DDT (8)
- Endrin (3.7)
- Arsenic (10)
- Cadmium (1.8)
- Chromium (22)
- Lead (27)
- Manganese (2.8)
- Nickel (360)
- Zinc (13)

Upper 95% Confidence Limit

- Chlordane (41)
- DDE (4.1)
- DDT (46)
- Endrin (6.9)
- PCBs (1.5)
- Arsenic (13)
- Cadmium (2.2)
- Chromium (24)
- Lead (37)
- Manganese (3.1)
- Nickel (430)
- Zinc (15)

Nickel had the highest hazard indices. The majority (84%-100%) of the hazard index for pesticides, PCBs, cadmium, chromium, lead, nickel, and zinc was due to earthworm ingestion, while the majority (68%) of the arsenic hazard index was due to soil ingestion. Manganese had approximately equal contributions to the hazard index from each exposure route.

The results show a potential for adverse effects to occur to insectivorous small mammals that feed at the site.

Table 5–1

Summary of Hazard Quotients/Indices for the Northern Short–Tailed Shrew

Chemical	Hazard Quotient for Soil Ingestion		Hazard Quotient for Earthworm Ingestion		Chemical–Specific Hazard Indices	
	Mean	95% UCL	Mean	95% UCL	Mean	95% UCL
Organics						
Chlordane	2.5E–01	8.4E–01	1.2E+01	4.0E+01	1.2E+01	4.1E+01
DDD	9.7E–04	3.3E–03	7.8E–02	2.6E–01	7.9E–02	2.7E–01
DDE	1.2E–02	5.6E–02	8.8E–01	4.0E+00	8.9E–01	4.1E+00
DDT	7.7E–02	4.5E–01	7.9E+00	4.6E+01	8.0E+00	4.6E+01
Dieldrin	1.0E–02	2.8E–02	9.6E–01	2.7E+00	9.7E–01	2.7E+00
Endrin	1.0E–01	1.9E–01	3.6E+00	6.7E+00	3.7E+00	6.9E+00
PAHs (total)	1.7E–02	4.2E–02	5.4E–02	1.3E–01	7.1E–02	1.8E–01
Benzo(a)anthracene	1.7E–03	5.8E–03	4.5E–03	1.5E–02	6.2E–03	2.1E–02
Benzo(a)pyrene	1.9E–03	2.7E–03	6.4E–03	8.9E–03	8.3E–03	1.2E–02
Benzo(b)fluoranthene	1.3E–03	2.9E–03	2.6E–03	5.9E–03	3.9E–03	8.9E–03
Benzo(g,h,i)perylene	1.1E–03	3.3E–03	1.6E–03	4.8E–03	2.8E–03	8.1E–03
Benzo(k)fluoranthene	1.7E–03	4.5E–03	3.5E–03	9.1E–03	5.2E–03	1.4E–02
Chrysene	1.8E–03	9.7E–03	7.5E–03	4.1E–02	9.2E–03	5.1E–02
Dibenz(a,h)anthracene	2.8E–04	3.5E–04	1.3E–03	1.6E–03	1.6E–03	2.0E–03
Fluoranthene	2.7E–03	4.1E–03	9.5E–03	1.5E–02	1.2E–02	1.9E–02
Indeno(1,2,3–cd)pyrene	1.4E–03	3.0E–03	5.5E–03	1.2E–02	6.9E–03	1.5E–02
Pyrene	3.1E–03	5.2E–03	1.2E–02	2.0E–02	1.5E–02	2.5E–02
PCB (Aroclor 1260)	4.4E–03	6.8E–03	9.2E–01	1.5E+00	9.3E–01	1.5E+00
Inorganics						
Arsenic	7.1E+00	8.6E+00	3.3E+00	4.0E+00	1.0E+01	1.3E+01
Cadmium	4.1E–02	4.7E–02	1.8E+00	2.1E+00	1.8E+00	2.2E+00
Chromium	2.6E+00	2.9E+00	1.9E+01	2.1E+01	2.2E+01	2.4E+01
Copper	3.7E–02	3.8E–02	1.6E–01	1.6E–01	2.0E–01	2.0E–01
Lead	4.5E+00	6.1E+00	2.3E+01	3.1E+01	2.7E+01	3.7E+01
Manganese	1.3E+00	1.5E+00	1.4E+00	1.6E+00	2.8E+00	3.1E+00
Nickel	2.0E+01	2.3E+01	3.4E+02	4.1E+02	3.6E+02	4.3E+02
Zinc	1.3E–01	1.5E–01	1.3E+01	1.5E+01	1.3E+01	1.5E+01

5.2.2 White-Footed Mouse

Potential risk to the white-footed mouse was estimated by comparing the estimated daily doses for the chemicals of potential concern (Table 3-8) with the reference toxicity values derived for the mouse (Table 4-2). The resulting hazard indices for the white-footed mouse are presented in Table 5-2. Hazard indices were calculated based on the arithmetic mean of the soil concentrations as well as the upper 95% confidence limit of the mean.

As shown in Table 5-2, the following chemicals exceeded a hazard index of one:

Mean	Upper 95% Confidence Limit
• Chlordane (2.4)	• Chlordane (8.3)
• Arsenic (1.9)	• Arsenic (2.3)
• Lead (1.3)	• Lead (1.8)
• Nickel (16)	• Manganese (1.1)
• Zinc (1.2)	• Nickel (19)
	• Zinc (1.4)

Nickel and chlordane had the highest hazard indices. The hazard indices for most of the metals (arsenic, lead, manganese, and zinc) were just slightly above one. The majority (71%-98%) of the hazard index for chlordane, manganese, nickel, and zinc was due to seed ingestion, while the majority (69%-77%) of the arsenic and lead hazard indices was due to soil ingestion.

The results show a potential for adverse effects to occur to herbivorous small mammals that feed at the site.

5.2.3 American Robin

Potential risk to the robin was estimated by comparing the estimated daily doses for the chemicals of potential concern (Table 3-11) with the reference toxicity values derived for the robin (Table 4-3). The resulting hazard indices for the robin are presented in Table 5-3. Hazard indices were calculated based on the arithmetic mean of the soil concentrations as

Table 5–2

Summary of Hazard Quotients/Indices for the White–footed Mouse

Chemical	Hazard Quotient for Soil Ingestion		Hazard Quotient for Seed Ingestion		Chemical–Specific Hazard Indices	
	Mean	95% UCL	Mean	95% UCL	Mean	95% UCL
Organics						
Chlordane	5.0E–02	1.7E–01	2.4E+00	8.1E+00	2.4E+00	8.3E+00
DDD	2.0E–04	6.7E–04	1.3E–04	4.5E–04	3.3E–04	1.1E–03
DDE	2.5E–03	1.1E–02	2.7E–03	1.2E–02	5.2E–03	2.4E–02
DDT	1.6E–02	9.0E–02	4.5E–02	2.6E–01	6.1E–02	3.5E–01
Dieldrin	2.0E–03	5.7E–03	3.5E–02	9.9E–02	3.7E–02	1.1E–01
Endrin	2.1E–02	3.9E–02	3.7E–01	6.8E–01	3.9E–01	7.2E–01
PAHs (total)	3.4E–03	8.4E–03	8.2E–03	1.5E–02	1.2E–02	2.4E–02
Benzo(a)anthracene	3.5E–04	1.2E–03	3.9E–04	1.3E–03	7.4E–04	2.5E–03
Benzo(a)pyrene	3.9E–04	5.4E–04	3.5E–03	4.8E–03	3.9E–03	5.4E–03
Benzo(b)fluoranthene	2.6E–04	5.9E–04	1.6E–04	3.6E–04	4.2E–04	9.5E–04
Benzo(g,h,i)perylene	2.3E–04	6.7E–04	7.7E–05	2.2E–04	3.1E–04	8.9E–04
Benzo(k)fluoranthene	3.5E–04	9.1E–04	2.1E–04	5.5E–04	5.6E–04	1.5E–03
Chrysene	3.5E–04	2.0E–03	3.9E–04	2.2E–03	7.5E–04	4.1E–03
Dibenz(a,h)anthracene	5.6E–05	7.0E–05	3.9E–05	4.8E–05	9.5E–05	1.2E–04
Fluoranthene	5.4E–04	8.3E–04	1.5E–03	2.4E–03	2.1E–03	3.2E–03
Indeno(1,2,3–cd)pyrene	2.8E–04	6.1E–04	9.4E–05	2.0E–04	3.7E–04	8.2E–04
Pyrene	6.3E–04	1.1E–03	1.8E–03	3.1E–03	2.5E–03	4.1E–03
PCB (Aroclor 1260)	8.8E–04	1.4E–03	5.0E–04	7.9E–04	1.4E–03	2.2E–03
Inorganics						
Arsenic	1.4E+00	1.7E+00	4.3E–01	5.2E–01	1.9E+00	2.3E+00
Cadmium	8.2E–03	9.6E–03	6.1E–02	7.2E–02	7.0E–02	8.1E–02
Chromium	5.2E–01	5.8E–01	1.2E–01	1.3E–01	6.4E–01	7.1E–01
Copper	7.5E–03	7.6E–03	9.4E–02	9.5E–02	1.0E–01	1.0E–01
Lead	9.0E–01	1.2E+00	4.1E–01	5.6E–01	1.3E+00	1.8E+00
Manganese	2.7E–01	3.1E–01	6.8E–01	7.7E–01	9.5E–01	1.1E+00
Nickel	4.0E+00	4.7E+00	1.2E+01	1.4E+01	1.6E+01	1.9E+01
Zinc	2.7E–02	3.1E–02	1.2E+00	1.4E+00	1.2E+00	1.4E+00

Table 5–3

Summary of Hazard Quotients/Indices for the American Robin

Chemical	Hazard Quotient for Soil Ingestion		Hazard Quotient for Earthworm Ingestion		Chemical–Specific Hazard Indices	
	Mean	95% UCL	Mean	95% UCL	Mean	95% UCL
Organics						
Chlordane	1.8E–02	5.9E–02	8.3E–01	2.8E+00	8.4E–01	2.8E+00
DDD	2.2E–03	7.5E–03	1.7E–01	5.9E–01	1.8E–01	6.0E–01
DDE	5.6E–01	2.6E+00	3.9E+01	1.8E+02	4.0E+01	1.8E+02
DDT	4.8E–01	2.8E+00	4.8E+01	2.7E+02	4.8E+01	2.8E+02
Dieldrin	3.2E–03	8.9E–03	2.9E–01	8.3E–01	3.0E–01	8.4E–01
Endrin	2.5E–01	4.6E–01	8.4E+00	1.6E+01	8.7E+00	1.6E+01
PAHs (total)	NC	NC	NC	NC	NC	NC
Benzo(a)anthracene	NC	NC	NC	NC	NC	NC
Benzo(a)pyrene	NC	NC	NC	NC	NC	NC
Benzo(b)fluoranthene	NC	NC	NC	NC	NC	NC
Benzo(g,h,i)perylene	NC	NC	NC	NC	NC	NC
Benzo(k)fluoranthene	NC	NC	NC	NC	NC	NC
Chrysene	NC	NC	NC	NC	NC	NC
Dibenz(a,h)anthracene	NC	NC	NC	NC	NC	NC
Fluoranthene	NC	NC	NC	NC	NC	NC
Indeno(1,2,3–cd)pyrene	NC	NC	NC	NC	NC	NC
Pyrene	NC	NC	NC	NC	NC	NC
PCB (Aroclor 1260)	1.5E–03	2.3E–03	3.1E–01	4.8E–01	3.1E–01	4.8E–01
Inorganics						
Arsenic	5.3E–02	6.4E–02	2.4E–02	2.9E–02	7.7E–02	9.3E–02
Cadmium	1.9E–02	2.2E–02	8.3E–01	9.7E–01	8.5E–01	9.9E–01
Chromium	2.8E–02	3.1E–02	2.0E–01	2.3E–01	2.3E–01	2.6E–01
Copper	2.0E–01	2.0E–01	8.3E–01	8.4E–01	1.0E+00	1.0E+00
Lead	9.0E–01	1.2E+00	4.5E+00	6.2E+00	5.4E+00	7.4E+00
Manganese	1.9E–01	2.1E–01	1.9E–01	2.2E–01	3.8E–01	4.3E–01
Nickel	1.9E–01	2.2E–01	3.1E+00	3.7E+00	3.3E+00	3.9E+00
Zinc	6.0E–02	6.8E–02	5.6E+00	6.3E+00	5.6E+00	6.4E+00

NC – Could not be calculated

well as the upper 95% confidence limit of the mean. The hazard indices presented for chlordane, DDD, PCBs, manganese, and nickel are based on acute endpoints, since only acute toxicity data were available for deriving the RTVs. The hazard indices for all other chemicals are based on chronic endpoints.

As shown in Table 5-3, the following chemicals exceeded a hazard index of one:

Mean	Upper 95% Confidence Limit
• DDE (40)	• Chlordane (2.8)
• DDT (48)	• DDE (180)
• Endrin (8.7)	• DDT (280)
• Lead (5.4)	• Endrin (16)
• Nickel (3.3)	• Lead (7.4)
• Zinc (5.6)	• Nickel (3.9)
	• Zinc (6.4)

DDE and DDT had the highest hazard indices. The majority (83%-99%) of the hazard index for these contaminants of concern can be attributed to earthworm ingestion. Note the potential for acute risk to the robin due to chlordane in soil.

The results show a potential for adverse effects to occur to omnivorous passerines that feed at the site.

5.2.4 Song Sparrow

Potential risk to the song sparrow was estimated by comparing the estimated daily doses for the chemicals of potential concern (Table 3-14) with the reference toxicity values derived for the song sparrow (Table 4-3). The resulting hazard indices for the song sparrow are presented in Table 5-4. Hazard indices were calculated based on the arithmetic mean of the soil concentrations as well as the upper 95% confidence limit of the mean. The hazard indices presented for chlordane, DDD, PCBs, manganese, and nickel are based on acute endpoints, since only acute toxicity data were available for deriving the RTVs. The hazard indices for all other chemicals are based on chronic endpoints.

Table 5-4

Summary of Hazard Quotients/Indices for the Song Sparrow

Chemical	Hazard Quotient for Soil Ingestion		Hazard Quotient for Seed Ingestion		Chemical-Specific Hazard Indices	
	Mean	95% UCL	Mean	95% UCL	Mean	95% UCL
Organics						
Chlordane	2.1E-03	7.0E-03	2.0E-01	6.7E-01	2.0E-01	6.7E-01
DDD	2.6E-04	8.9E-04	3.5E-04	1.2E-03	6.1E-04	2.1E-03
DDE	6.6E-02	3.0E-01	1.4E-01	6.6E-01	2.1E-01	9.6E-01
DDT	5.6E-02	3.2E-01	3.2E-01	1.9E+00	3.8E-01	2.2E+00
Dieldrin	3.7E-04	1.0E-03	1.3E-02	3.6E-02	1.3E-02	3.7E-02
Endrin	2.9E-02	5.4E-02	1.0E+00	1.9E+00	1.0E+00	1.9E+00
PAHs (total)	NC	NC	NC	NC	NC	NC
Benzo(a)anthracene	NC	NC	NC	NC	NC	NC
Benzo(a)pyrene	NC	NC	NC	NC	NC	NC
Benzo(b)fluoranthene	NC	NC	NC	NC	NC	NC
Benzo(g,h,i)perylene	NC	NC	NC	NC	NC	NC
Benzo(k)fluoranthene	NC	NC	NC	NC	NC	NC
Chrysene	NC	NC	NC	NC	NC	NC
Dibenz(a,h)anthracene	NC	NC	NC	NC	NC	NC
Fluoranthene	NC	NC	NC	NC	NC	NC
Indeno(1,2,3-cd)pyrene	NC	NC	NC	NC	NC	NC
Pyrene	NC	NC	NC	NC	NC	NC
PCB (Aroclor 1260)	1.7E-04	2.7E-04	2.0E-04	3.1E-04	3.7E-04	5.9E-04
Inorganics						
Arsenic	6.2E-03	7.6E-03	3.7E-03	4.5E-03	1.0E-02	1.2E-02
Cadmium	2.2E-03	2.6E-03	3.4E-02	3.9E-02	3.6E-02	4.2E-02
Chromium	3.3E-03	3.7E-03	1.5E-03	1.6E-03	4.8E-03	5.3E-03
Copper	2.4E-02	2.4E-02	5.9E-01	6.0E-01	6.1E-01	6.2E-01
Lead	1.1E-01	1.5E-01	9.6E-02	1.3E-01	2.0E-01	2.8E-01
Manganese	2.2E-02	2.5E-02	1.1E-01	1.2E-01	1.3E-01	1.5E-01
Nickel	2.2E-02	2.6E-02	1.3E-01	1.5E-01	1.5E-01	1.8E-01
Zinc	7.0E-03	8.0E-03	6.3E-01	7.2E-01	6.4E-01	7.3E-01

NC - Could not be calculated

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As shown in Table 5-4, none of the chemicals exceeded a hazard index of one based on the mean concentrations, and only two chemicals slightly exceeded a hazard index of one based on the upper 95% confidence limit of the mean - DDT (2.2) and Endrin (1.9).

The results show that there is very little potential for adverse effects to occur to seed-eating passerines that feed at the site. However, the potential for chronic effects to occur from exposure to chlordane, DDD, PAHs, PCBs, manganese, and nickel could not be evaluated.

5.3 Risk Characterization for Terrestrial Vegetation

Potential effects to terrestrial plants at the site were assessed by comparing soil concentrations to available phytotoxicity data (Table 4-4). There were very little phytotoxicity data available for the organic chemicals. A much greater amount of phytotoxicity data were available for the inorganics. Exceedances of phytotoxicity data occurred for arsenic, cadmium, copper, lead, and zinc. Arsenic soil concentrations at a number of locations at the site exceeded levels at which yield reductions have been reported in the literature, and exceeded "phytotoxically excessive" concentrations as reported by Kabata-Pendias and Pendias (1984). However, all arsenic concentrations fell below the concentration reported as a "tolerable amount" by El-Bassam and Tietjen (1977). The maximum detected value of cadmium in the vicinity of the propellant storage area at the site (sample location 16SS01) exceeded the concentration reported to cause growth retardation and leaf discoloration. Also, cadmium concentrations at two locations at the site (16SS01, 14SUB01) exceeded concentrations reported in the literature to reduce spore germination in ferns. There are a number of locations at the site where copper and lead concentrations exceeded levels at which yield reduction or growth inhibition have been reported in the literature, and exceeded concentrations reported as "phytotoxically excessive" (Kabata-Pendias and Pendias, 1984). Zinc concentrations at three locations at the site (16SS01, 14SUB01, 14SS01) exceeded levels at which yield reductions have been reported in the literature, and exceeded concentrations reported as "phytotoxically excessive" (Kabata-Pendias and Pendias, 1984).

These results show that there are some locations at the site at which phytotoxic effects may occur.

5.4 Risk Characterization for Soil Invertebrates

Potential effects to soil invertebrates inhabiting the site were assessed by comparing soil concentrations to available soil invertebrate toxicity data (Table 4-5). Toxicity data were available for 6 of the organics and the majority of the inorganic chemicals of potential concern. Exceedances of toxicity data were observed for chlordane, DDE, copper, and zinc. The maximum detected concentration of chlordane (sampling location 13SS02) exceeded a LOEC (lowest observed effect concentration) of 6.25 mg/kg for sperm count depression in earthworms. At 2 out of the 34 sampling locations (13SS02 and 17SB03), DDE concentrations exceeded a toxicity value of 1.5 mg/kg for significant epidermal changes such as blisters and erythema of the clitellum in earthworms. At 37% of the soil sampling locations (13/35), copper concentrations exceeded the EC_{50} (50% effect concentration) of 53 mg/kg for cocoon production in earthworms. In addition, the maximum detected value of copper at the site in the vicinity of Building 295 (14SUB01) exceeded earthworm LC_{50}s (lethal concentration for 50% of the organisms). Zinc concentrations at 3 out of 35 locations at the site (16SS01, 14SUB01, 14SS01) exceeded an EC_{50} value of 53 mg/kg for cocoon production in earthworms. The maximum concentration of zinc in the vicinity of the propellant storage area (sample location 16SS01) exceeded LC_{50}s reported for earthworms.

6.0 UNCERTAINTY ANALYSIS

An ecological risk assessment is subject to a wide variety of uncertainties. Virtually every step in the risk assessment process involves numerous assumptions which contribute to the total uncertainty in the final evaluation of risk.

In the exposure assessment, numerous assumptions were made in order to estimate daily doses for selected indicator species (i.e., Northern short-tailed shrew, white-footed mouse, American robin, and song sparrow). Since limited site-specific information was available, assumptions were made regarding chemical concentrations in food items (*e.g.*, earthworms, plant seeds) and ingestion rates. In general, an effort was made to use assumptions that were conservative, yet realistic.

The interpretation and application of toxicological data in the toxicity assessment are probably the greatest sources of uncertainty in an ecological risk assessment. Frequently, data from literature sources are not specific to the indicator species selected, and therefore, extrapolation of the data to the species of concern is necessary. When extrapolating ecological data, every effort was made to use data from the most closely related species to the indicator organism. Even so, species sensitivities may vary even among closely related species. Variations in species sensitivity may be due to differences in some of the following factors: tolerance thresholds, toxic symptoms exhibited, time period until toxic effects are observed, and metabolism of ingested chemical.

In calculating RTVs, safety factors are applied to toxicity data to account for differences in species and difference in toxicological endpoints (*e.g.*, LD_{50}, NOAEL, LOAEL). The safety factors which were applied were either recommended by the EPA, developed from literature reviews of toxicological data, or based on best professional judgment. There are uncertainties associated with applying safety factors. For example, in deriving RTVs based on data from a different species, a safety factor is used to protect for the possibility that the indicator species may be more sensitive to a chemical exposure than the test species, even

though the opposite may be true. Thus, the potential exists for developing an overly protective RTV.

An additional uncertainty in developing RTVs is estimating a mg/kg-day intake from a dose reported as ppm in the diet. Where information from the study was not available to make this conversion, average ingestion rates and body weights were used to estimate an RTV.

An uncertainty which may result in an underestimate of risk in the risk characterization is the absence of toxicity data (*e.g.*, avian toxicity data for PAHs). In the absence of such information, the potential risk from exposure to chemicals of potential concern cannot be quantitatively evaluated.

Another uncertainty that may result in an underestimate of risk is associated with the use of RTVs developed from limited toxicological data. Since few data exist for dietary exposure to some chemicals (*e.g.*, mammalian exposure to DDD and PAHs) it is uncertain whether or not the existing studies have identified the most sensitive endpoints. In addition, for some chemical only acute data were available (*e.g.*, avian exposure to chlordane, DDD, and Aroclor 1260), and therefore does not account for potential chronic effects from exposure to these chemicals. Thus, basing the RTV on one of these studies may not protect against adverse effects to the most sensitive toxicological endpoint.

Risks were calculated on a chemical-by-chemical basis. Calculating risk in this manner does not account for additivity, synergism, or antagonism of chemicals to which receptors are exposed. This procedure may result in an overestimation or underestimation of potential risk.

The following text provides a brief discussion of the primary uncertainties associated with the risk evaluation for the indicator species/communities. The discussion focuses on those chemicals and/or exposure routes that are responsible for the majority of the risk.

6.1 Northern Short-tailed Shrew

Exposure Assessment:

- It was assumed that the Northern short-tailed shrew is present at the site. This assumption is based on the similarity between habitat conditions at the site and descriptions of short-tailed shrew habitat in the scientific literature. Moreover, the short-tailed shrew is known to occur locally (DeGraaf and Rudis, 1986).

- The diet of the shrew in a given location is based on food availability and can consist of the following organisms: earthworms, spiders, millipedes, centipedes, sow bugs, small vertebrates, plants, and insect larvae and pupae (DeGraaf and Rudis, 1986). Since data are not available to estimate chemical concentrations in other probable food sources, exposure dose estimates were based on exclusive consumption of earthworms. Since earthworms inhabit and ingest soil, they may be more efficient accumulators of soil contaminants than some of these other organisms. Thus, the assumption of an exclusive earthworm diet may overestimate the hazard to the shrew.

- There is some uncertainty associated with the food ingestion rate used for the short-tailed shrew. A number of references (EPA, 1993; Churchfield, 1990; Opresko et al., 1994) report that short-tailed shrews ingest approximately 60% of their body weight per day, or 9 g/day (as wet weight). This value (as converted to dry weight) was used in this assessment. This ingestion rate was measured in the laboratory under conditions of thermoneutrality (Merritt, 1995). Baker (1983), however, reported that physiological data measured for the short-tailed shrew (*i.e.*, heartbeat of 740-760/minute, respiration rate of 164 breaths/min., body temperature of 38°C, metabolic rate of 3.18 cm^3 O_2/gm/hr) "point to the need for the short-tailed shrew to eat between half and three times its body weight per day". The ingestion rates that Baker presents are not observed values, but were estimated based on physiological data (Merritt, 1995). For comparison purposes, the hazard indices for the shrew were recalculated using the midpoint (175% of the body weight) of the range of ingestion rates presented by Baker (1983). A food ingestion rate of 175% of the body weight was converted to 26 g/day wet weight intake, assuming a body weight of 15 g. Assuming a moisture content of 75% in earthworms, a dry weight intake of 6.6 g/day was estimated. The soil ingestion rate was estimated to be 0.68 g/day based on 10.4% of the dry weight intake. The resulting hazard indices were as follows:

Mean	Upper 95% Confidence Limit
- Chlordane (29)	- Chlordane (97)
- DDE (2.1)	- DDE (9.6)
- DDT (19)	- DDT (110)
- Dieldrin (2.3)	- Dieldrin (6.4)
- Endrin (8.8)	- Endrin (16)
- PCB (2.2)	- PCB (3.4)
- Arsenic (24)	- Arsenic (30)
- Cadmium (4.3)	- Cadmium (5.1)
- Chromium (51)	- Chromium (57)
- Lead (64)	- Lead (88)
- Manganese (6.5)	- Manganese (7.4)
- Nickel (860)	- Nickel (1000)
- Zinc (30)	- Zinc (35)

These hazard indices are approximately 2.5 times greater than those presented in the body of the report, and most likely represent an upperbound estimate of risk for the shrew.

- There are a number of difficulties associated with applying literature-based earthworm BAFs to a given site. Environmental variables, such as soil characteristics, obscure the underlying relationship between concentrations in soils and in earthworms. Earthworms selectively feed on plant debris and soil organic matter, and consequently, soil concentrations may not represent true exposure concentrations. Also, different earthworm species bioaccumulate chemicals at different rates (Beyer, 1990). Thus, there is uncertainty associated with applying literature-based earthworm BAFs to the AMTL site.

- It is not known how available metals and other inorganics in earthworm tissue are to predators. The presence of high levels of metals in earthworm tissue is not adequate proof that they will be absorbed by the predator (Lee, 1985). Thus, if metals are not in a bioavailable form in earthworms, they may not pose a hazard to wildlife at the site.

- The chemical form of a metal is an important factor in determining the level of exposure at which toxicity appears (Lee, 1985). The metal concentrations in soils at the site were analyzed as total metals, and thus the actual form of the metal in soils and in earthworms is not known. As a general rule, the more bioavailable forms of chemicals are used in toxicity tests. Thus, it is possible that the form of a metal in the earthworms at the site is in a less bioavailable form than that used in the study on which the RTV is based. In such a case, the estimated hazard from exposure to such a chemical would be overestimated. For nickel, it is important to note that the shrew RTV is based on a drinking water study in which a soluble salt of nickel was used. Nickel is most likely more available for uptake from water, as a soluble salt,

than from soils or earthworms. This indicates that the hazard to nickel may have been overestimated at the site.

Effects Characterization/Risk Characterization:

- No toxicity data were available specifically for the shrew; therefore, data from other small mammal species were used.

- The RTV for nickel was based on a chronic effect dose for rats, in which an increase in deaths and runts were observed in the young. A safety factor of 5 was used to extrapolate from a chronic effect dose to a safe chronic dose. It is not known whether this safety factor over- or under-estimates risk. An additional safety factor of 5 was used to extrapolate between species. If the shrew is as or less sensitive to nickel exposure than the rat, the RTV may result in an overestimation of risk. Also, as mentioned previously, the nickel was administered in drinking water as a soluble salt in the RTV study (Schroeder and Mitchener, 1971), which is a very bioavailable form of nickel. Although the extent of nickel bioavailability from earthworms or soil is not known, it is most likely not as bioavailable as the form of nickel in the RTV study. Thus, the use of this study to develop the nickel RTV may overestimate the risk to small mammals.

- The RTV for DDT was based on a chronic NOAEL for pup growth in rats. The NOAEL was 1 mg/kg-day, with an associated LOAEL of 10 mg/kg-day (Clement and Okey, 1974). Since the true no effect level lies somewhere between 1 and 10 mg/kg-day, the RTV most likely overestimates risk. In addition, an inter-species safety factor of 5, which was applied to the RTV, may result in an overestimate of risk if the shrew is as or less sensitive to chlordane exposure compared to the rat.

- The RTV for lead was based on a chronic NOAEL for depressed immunity in rats. A safety factor of 5 was used to extrapolate between species. If the shrew is as or less sensitive to nickel exposure than the rat, the RTV may result in an overestimation of risk. In the RTV study, the lead was administered in drinking water as lead acetate (Luster et al., 1978), which is a bioavailable form of lead. Although the extent of lead bioavailability from earthworms or soil is not known, it is most likely not as bioavailable as the form of lead in the RTV study. Thus, the use of this study to develop the lead RTV may overestimate the risk to small mammals.

- The RTV for chlordane was based on a chronic NOAEL for liver lesions in mice. This NOAEL was based on 5 ppm of chlordane administered in the diet. Although liver lesions were observed at this dose, these effects were not statistically significant. Significant effects were observed at the highest dose (12.5 ppm). The authors stated, however, that although changes in the liver appeared earlier and at a greater frequency in mice fed 12.5 ppm of chlordane, these changes only appeared at the end of what would be the

normal lifespan for these mice (2 years). Thus, there is some question as to the ecological significance of this endpoint. It is possible that liver lesions would not significantly affect small mammal health and population levels in the field. Thus, there is uncertainty in the ecological significance of the chlordane RTV.

- Since metals occur naturally in soils, one needs to consider whether metals detected at the site are due to contamination or based on natural background levels. Table A-8 (Appendix A) presents means and ranges of background metal concentrations measured in U.S. soils. The ranges that are presented often span many orders of magnitude, and are most likely a reflection of the diverse environments that were sampled. Thus, these background values can only be used as general guidance in determining whether a metal is at background levels at the site. Other factors need to be considered, such as the range and distribution of metal concentrations at the site. The metals at the site which exceeded background ranges at one or more locations were cadmium, copper, lead, and zinc. Cadmium exceeded background ranges at sampling locations 16SS01, 14SUB01, and 14SUB02. Copper exceeded background ranges at sampling location 14SUB01. Lead exceeded background levels at a number of locations. Zinc exceeded background ranges as reported in Kabata-Pendias and Pendias (1984) at sampling locations 16SS01, 14SUB01, 14SS01. For other metals such as arsenic, chromium, manganese, and nickel, it becomes more difficult to determine what is or is not due to background. Although these metals fall within the natural background ranges, there are a few site values which appear to be higher than the majority of values measured at the site. For example, the maximum arsenic concentration of 52 mg/kg (sampling location 14SUB01) appears to be slightly higher than other arsenic values. For chromium there are a few values (sampling locations 16SS01 and 14SS03) that appear to be slightly elevated. For manganese there are a few values (sampling locations 14SUB01, 13SUB02, and 16SS01) that appear to be slightly elevated. For nickel, it appears that there may be some elevated concentrations (possibly locations 14SS03 and 12SUB01). Approximately 85% of the nickel concentrations at the site fell within a range of 10 to 45 ppm. There were three concentrations that fell within 50-60 ppm, one value at 73 ppm (12SUB01), and the maximum concentration of nickel at 99 ppm (14SS03). Although some values appear to be slightly elevated it is possible that these values are upper-end background concentrations. Thus, there is uncertainty associated with whether risks determined for some metals (particularly arsenic, chromium, manganese, and nickel) are due to background or to site-related activities.

6.2 <u>White-Footed Mouse</u>

Exposure Assessment:

- It was assumed that the white-footed mouse is present at the site. This assumption is based on the similarity between habitat conditions at the site and descriptions of white-footed mouse habitat in the scientific literature. Moreover the white-footed mouse is known to occur locally (DeGraaf and Rudis, 1986).

- Chemical concentrations in plant seeds are dependent on such factors as plant species considered, site-specific conditions (*i.e.*, soil type, soil pH, soil organic content), chemical species, etc. Plant uptake factors (PUFs) for organics were calculated based on a regression equation which incorporates chemical-specific log Kows. Uncertainty exists in using predicted values such as these. The PUFs used for inorganics were based on data from Baes et al. (1984), who derived uptake factors based on a literature review, and comparisons of observed and predicted elemental concentrations in plants (Baes et al. 1984). Inorganics can exist in soils as free ionic forms, inorganic ion pairs, inorganic complexes, organic complexes, etc., each with its own propensity toward biouptake, trophic transfer, and subsequent toxicity. Because the form of the element in the environment is difficult to predict or is seldom measured, prediction of the mobilization and uptake of metals is highly uncertain. Therefore, the concentrations of chemicals in plant seeds, and subsequent risk from ingestion of seeds, is a major uncertainty.

- The chemical form of a metal is an important factor in determining the level of exposure at which toxicity appears (Lee, 1985). The metal concentrations in soils at the site were analyzed as total metals, and thus the actual form of the metal in soils and in plants is not known. As a general rule, the more bioavailable forms of chemicals are used in toxicity tests. Thus, it is possible that the form of a metal in plants at the site is in a less bioavailable form than that used in the study on which the RTV is based. In such a case, the estimated hazard from exposure to such a chemical would have been overestimated. As discussed for the shrew, the nickel RTV is based on a drinking water study in which a soluble salt of nickel was used. Nickel is most likely more available from water, as a soluble salt, than from soils or plants. This indicates that the hazard to nickel may have been overestimated at the site.

Effects Characterization/Risk Characterization:

- White-footed mouse toxicity data were not available for any chemicals of concern; therefore, interspecies extrapolation was required for all of the chemicals of concern. If the white-footed mouse is as or less sensitive to a chemical as compared to the test species, then the risk to the mouse will be overestimated.

- There is considerable uncertainty associated with the RTVs derived for nickel and chlordane, as discussed under the uncertainty analysis for the shrew.

- As discussed for the shrew, there is uncertainty associated with whether risks determined for some metals are due to background or to site-related activities.

6.3 American Robin

Exposure Assessment:

- The diet of the robin in a given location is based on food availability and can consist of the following organisms: earthworms, grasshoppers, beetles, cicadas, ants, termites, cutworms, caterpillars, butterflies, and berries (Terres, 1991). Since data are not available to estimate chemical concentrations in other probable food sources, exposure dose estimates were based on exclusive consumption of earthworms. Since earthworms inhabit and ingest soil, they may be more efficient accumulators of soil contaminants than some of these other organisms. Thus, the assumption of an exclusive earthworm diet may overestimate the hazard to the robin.

- As discussed under the uncertainty analysis for the shrew, there are many uncertainties associated with using literature-based bioaccumulation factors for earthworms.

- As discussed under the uncertainty analysis for the shrew, it is not known how available the metals and other inorganics in earthworm tissue are to predators.

Effects Characterization/Risk Characterization:

- No toxicity data were available for the robin; therefore, data from other bird species were used.

- Toxicity data for avian species were not available for PAHs; therefore, the potential risk from exposure to these chemicals could not be estimated for the robin.

- The RTV for DDT was based on a chronic NOAEL for eggshell thinning in mallards. This NOAEL was based on 2 ppm of DDT administered in the diet. The next highest dose that was tested was 20 ppm (LOAEL). Since the true no effect level lies somewhere between 2 and 20 ppm, the RTV most likely overestimates risk. In addition, an inter-species safety factor of 5, which was applied to the RTV, may result in an overestimate of risk if the robin is

as or less sensitive to DDT exposure compared with the mallard. Thus, there is some uncertainty associated with the avian RTV for DDT.

- The RTV for DDE was based on a chronic effect dose for eggshell thinning, eggshell cracking, and duckling survival in black ducks. Since there is no associated NOAEL reported in this study, it is uncertain whether this RTV results in an over- or under-estimation of risk.

- The RTVs for chlordane, DDD, PCBs, manganese, and nickel are based on acute endpoints, and extrapolated to acute no effect levels. The potential for chronic effects to occur based on exposure to these chemicals could not be evaluated due to a lack of sufficient chronic toxicity data.

6.4 Song Sparrow

Exposure Assessment:

- The diet of the song sparrow in a given location is based on food availability and can consist of the following organisms: seeds of grasses and weeds, wild fruits, beetles, grasshoppers, cutworms, army worms, ants, wasps, flies, termites, bugs, leafhoppers, etc. (Terres, 1991). Since data are not available to estimate chemical concentrations in other probable food sources, exposure dose estimates were based on exclusive consumption of plant seeds. It is uncertain whether this assumption may over- or under-estimate potential risk.

- As discussed under the uncertainty analysis for the white-footed mouse, there are many uncertainties associated with using literature-based plant uptake factors.

Effects Characterization/Risk Characterization:

- No toxicity data were available for the song sparrow; therefore, data from other bird species were used.

- Toxicity data for avian species were not available for PAHs; therefore, the potential risk from exposure to these chemicals could not be estimated for the song sparrow.

- The RTVs for chlordane, DDD, PCBs, manganese, and nickel are based on acute endpoints, and extrapolated to acute no effect levels. The potential for chronic effects to occur based on exposure to these chemicals could not be evaluated due to a lack of sufficient chronic toxicity data.

6.5 Terrestrial Vegetation

- Since phytotoxic effects are plant species-specific and directly related to ambient conditions (*i.e.*, soil type, soil pH, moisture content etc.), comparison of literature-based phytotoxicity data to soil concentrations at the AMTL site may not accurately illustrate potential hazards to on-site plants.

- Phytotoxicity of metals is dependent on the chemical form of the metal that was used in the study. Many of the secondary sources from which the phytotoxicity data were taken do not provide information on the form of the metal used in the studies.

- Some secondary references from which phytotoxicity data were taken do not provide information on the plant species used in the studies, or endpoints that were measured. For example, Kabata-Pendias and Pendias (1984) provide "phytotoxically excessive" levels, but do not provide any details on plant species or toxicological endpoints. Thus, there is uncertainty as to what these values represent.

- As discussed for the shrew, there is uncertainty associated with whether some metal concentrations at the site are due to background or to site-related activities.

6.6 Soil Invertebrates

- Since toxic effects to soil invertebrates are species-specific and directly related to ambient conditions (*i.e.*, soil type, soil pH, moisture content etc.), comparison of literature-based invertebrate toxicity data to soil concentrations at the AMTL site may not accurately illustrate potential hazards to these organisms.

- The potential effects on soil invertebrates from exposure to DDT was based on data reported in units of kg/hectare. These data were converted to a mg/kg basis, by assuming a soil density of 1.5 g/cm^3, and a mixing depth of 1 cm (EPA, 1990b). There are uncertainties associated with this conversion.

- The chemical form of a metal is an important factor in determining the level of exposure at which toxicity appears (Lee, 1985). The metal concentrations in soils at the site were analyzed as total metals, and thus the actual form of the metal in soils is not known. As a general rule, the more bioavailable forms of chemicals are used in toxicity tests. Thus, it is possible that the form of a metal in soils at the site is in a less bioavailable form than that used in toxicity studies.

- As discussed for the shrew, there is uncertainty associated with whether some metal concentrations at the site are due to background or to site-related activities.

7.0 CONCLUSIONS

The results of the terrestrial ecological risk assessment show the potential for adverse effects to occur to insectivorous small mammals, herbivorous small mammals, omnivorous passerines (*i.e.*, perching birds), plants, and soil invertebrates at the AMTL site.

For mammals, the highest hazard index was based on potential exposure to nickel. The nickel hazard indices observed for insectivorous mammals (*i.e.*, 360 to 420) were higher than those observed for herbivorous mammals (*i.e.*, 16 to 19). The majority of the hazard index for nickel, as well as most of the other contaminants was due to potential bioconcentration and exposure through earthworm or seed ingestion. The concentrations of nickel at the site fell within the means and ranges of background nickel concentrations measured in U.S. soils (Table A-8). On examining the distribution of nickel concentrations at the site, approximately 85% of the concentrations fell within concentrations of 10 to 45 ppm. There were three concentrations that fell within 50 to 60 ppm, one value at 73 ppm, and the maximum concentration of nickel at 99 ppm. It is uncertain whether the higher nickel concentrations are based on site-related activities or are upper-end background concentrations.

The basis of the RTV used for nickel also needs to be considered. The nickel RTV was based on chronic effects in rats, in which an increase in deaths and runts were observed in the young. An increase in deaths and runts in the young would potentially affect the population levels of small mammals at the site. However, in the RTV study, the nickel was administered in drinking water as a soluble salt, which is a very bioavailable form of nickel, and thus may tend to overestimate risk based on nickel exposure at the site.

In addition to nickel, there were a number of other chemicals that exceeded a hazard index of one for small mammals, particularly for the insectivorous small mammals (*e.g.*, chlordane,

DDT, lead, chromium, zinc). These hazard indices were generally much lower than those observed for nickel, and ranged from 1.5 to 46 for the insectivorous mammals, and 1.2 to 8.3 for herbivorous mammals.

The highest hazard indices observed for omnivorous passerines were based on exposure to DDT (48 to 280) and DDE (40 to 180). The majority of the hazard index for these chemicals, as well as for others, was due to earthworm ingestion. The RTV for DDT was based on a dietary study in which eggshell thinning was observed in mallards, and the RTV for DDE was based on eggshell thinning, eggshell cracking, and duckling survival in black ducks. Eggshell thinning and decrease in young survival would potentially affect bird population levels. Thus, the results show the potential for adverse reproductive effects in omnivorous passerines feeding at the site. Other chemicals which exceeded a hazard index of one included endrin (8.7 to 16), lead (5.4 to 7.4), zinc (5.6 to 6.4), nickel (3.3 to 3.9) and chlordane (2.8).

A comparison of soil concentrations at the site with phytotoxicity data show the potential for phytotoxic effects to occur at some locations on the site. Exceedances of phytotoxicity data occurred for arsenic, cadmium, copper, lead, and zinc. These metals occurred at concentrations on the site which have been shown to cause yield reductions, growth retardation, leaf discoloration, and reduced germination.

Potential effects to soil invertebrates may also occur at some locations at the site. Exceedances of toxicity data were observed for chlordane, DDE, copper, and zinc. The maximum detected concentrations of copper and zinc at the site, exceed LC_{50}s for earthworms, and a number of other locations exceeded an EC_{50} value for cocoon production in earthworms. The organics exceeded concentrations at which sperm count depression and epidermal changes have been observed in earthworms.

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APPENDIX A

SELECTION OF THE CHEMICALS OF POTENTIAL CONCERN

Table A-1

Selection of Chemicals of Potential Concern in Soils [a]

Chemicals	Range of Hits (mg/kg)			Frequency of Detection	Range of Quantitation Limits		Reason for Exclusion as a COPC
Organics							
Acenaphthene	0.084	–	0.479	7 / 28	0.041 –	4.100	See PAHs – low MW
Acenaphthylene	0.163	–	4.190	9 / 28	0.033 –	4.600	See PAHs – low MW
Acetone	0.012	–	0.051	5 / 23	0.011 –	3.300	Below Screening Levels
Aldrin	0.006	–	0.008	2 / 34	0.001 –	1.300	Below Screening Levels; low frequency of detection
Alpha–Chlordane	0.005	–	0.155	9 / 11	0.002 –	0.002	
Alpha–Endosulfan	0.002	–	0.014	4 / 33	0.001 –	1.000	Below Screening Levels; low frequency of detection
Alpha–Hexachlorocyclohexane		–		0 / 34	0.003 –	1.300	Not detected
Anthracene	1.590	–	14.500	4 / 28	0.540 –	5.400	See PAHs – low MW
Benzene	0.258	–	0.258	1 / 23	0.003 –	0.100	Below Screening Levels; low frequency of detection
Benzo (a) anthracene	0.214	–	31.500	21 / 28	0.041 –	3.000	See PAHs – high MW
Benzo (a) pyrene	0.827	–	36.600	6 / 28	0.380 –	3.800	See PAHs – high MW
Benzo (b) fluoranthene	0.713	–	15.400	12 / 28	0.310 –	3.600	See PAHs – high MW
Benzo (g,h,i) perylene	0.378	–	13.600	13 / 28	0.180 –	2.400	See PAHs – high MW
Benzo (k) fluoranthene	0.406	–	23.600	15 / 28	0.130 –	8.000	See PAHs – high MW
Benzoic acid		–		0 / 28	1.700 –	20.000	Not Detected
Benzyl alcohol	1.290	–	1.290	1 / 28	0.032 –	3.000	Below Screening Levels; low frequency of detection
Beta–Endosulfan	0.001	–	0.013	6 / 33	0.001 –	2.400	Below Screening Levels
Beta–Hexachlorocyclohexane		–		0 / 33	0.008 –	3.600	Not Detected
Bis (2–chloroethyl) ether		–		0 / 28	0.330 –	3.300	Not Detected
Bis (2–chloroethyoxy) methane		–		0 / 28	0.190 –	3.000	Not Detected
Bis (2–chloroisopropyl) ether		–		0 / 28	0.300 –	3.000	Not Detected
Bis (2–ethylhexyl) phthalate		–		0 / 28	0.390 –	3.900	Not Detected
Bromodichloromethane		–		0 / 24	0.003 –	0.200	Not Detected
Bromofluorobenzene, 4–		–		0 / 13	0.600 –	0.600	Not Detected
Bromoform		–		0 / 24	0.018 –	0.200	Not Detected
Bromomethane		–		0 / 24	0.010 –	0.260	Not Detected
Bromophenylphenyl ether, 4–		–		0 / 29	0.041 –	3.000	Not Detected
Butanone, 2–	0.018	–	0.018	1 / 24	0.010 –	4.300	Below Screening Levels; low frequency of detection
Butylbenzyl phthalate	0.476	–	1.100	3 / 29	0.300 –	3.000	Below Screening Levels; low frequency of detection
Carbon disulfide		–		0 / 23	0.005 –	0.600	Not Detected
Carbon tetrachloride		–		0 / 23	0.005 –	0.310	Not Detected
Chlordane	0.324	–	9.360	16 / 33	0.068 –	30.000	
Chloroaniline, 4–		–		0 / 28	0.300 –	3.000	Not Detected
Chlorobenzene		–		0 / 23	0.003 –	0.100	Not Detected
Chloroethane		–		0 / 23	0.022 –	0.640	Not Detected
Chloroethylvinyl ether, 2–		–		0 / 23	0.048 –	0.500	Not Detected
Chloroform		–		0 / 23	0.002 –	0.240	Not Detected
Chloromethane		–		0 / 23	0.010 –	0.960	Not Detected
Chloronaphthalene, 2–		–		0 / 28	0.240 –	3.200	Not Detected
Chlorophenol, 2–		–		0 / 28	0.055 –	3.000	Not Detected
Chlorophenylmethyl sulfide, p–		–		0 / 28	0.097 –	3.700	Not Detected
Chlorophenylmethyl sulfone, p–		–		0 / 28	0.066 –	6.900	Not Detected
Chlorophenylmethyl sulfoxide,		–		0 / 28	0.270 –	2.700	Not Detected
Chlorophenylphenyl ether, 4–		–		0 / 28	0.170 –	3.000	Not Detected
Chrysene	0.076	–	33.900	16 / 28	0.032 –	4.500	See PAHs – high MW
DDD	0.004	–	3.480	16 / 34	0.003 –	0.064	
DDE	0.004	–	6.330	26 / 34	0.003 –	0.068	
DDT	0.010	–	5.200	17 / 33	0.004 –	4.100	
Delta–Hexachlorocyclohexane	0.020	–	0.034	3 / 34	0.005 –	0.210	Low frequency of detection; 1 hit only slightly exceeds SL
Di–N–butyl phthalate		–		0 / 28	0.300 –	3.000	Not Detected
Di–N–octyl phthalate		–		0 / 28	0.230 –	5.900	Not Detected
Dibenz (a,h) anthracene	0.468	–	3.340	3 / 28	0.200 –	2.000	See PAHs – high MW
Dibenzofuran		–		0 / 28	0.038 –	3.000	Not Detected
Dibromochloromethane		–		0 / 23	0.014 –	0.250	Not Detected
Dibromochloropropane		–		0 / 18	0.071 –	0.071	Not Detected
Dichlorobenzene, 1,2–		–		0 / 28	0.001 –	0.042	Not Detected
Dichlorobenzene, 1,3–		–		0 / 28	0.002 –	0.042	Not Detected
Dichlorobenzene, 1,4–		–		0 / 28	0.001 –	0.034	Not Detected
Dichlorobenzidine, 3,3'–		–		0 / 28	0.200 –	2.000	Not Detected
Dichloroethane, 1,1–		–		0 / 23	0.002 –	0.490	Not Detected
Dichloroethane, 1,2–		–		0 / 23	0.003 –	0.320	Not Detected
Dichloroethenes, 1,2– (cis and		–		0 / 23	0.002 –	0.320	Not Detected
Dichloroethylene, 1,1–		–		0 / 23	0.017 –	0.270	Not Detected
Dichlorophenol, 2,4–		–		0 / 28	0.065 –	3.000	Not Detected
Dichloropropane, 1,2–		–		0 / 23	0.002 –	0.530	Not Detected
Dichloropropane, 1,3–		–		0 / 23	0.001 –	0.200	Not Detected
Dichloropropene, 1,3– trans		–		0 / 23	0.005 –	0.600	Not Detected
Dichloropropylene, 1,3– cis		–		0 / 23	0.005 –	0.600	Not Detected
Dicyclopentadiene		–		0 / 18	0.570 –	0.570	Not Detected
Dieldrin	0.007	–	0.312	14 / 34	0.002 –	0.079	
Diethyl phthalate		–		0 / 28	0.240 –	3.000	Not Detected
Dimethyl phthalate		–		0 / 28	0.063 –	3.000	Not Detected
Dimethylbenzene, 1,2– / o–Xyle		–		0 / 10	0.005 –	0.006	Not Detected

Table A-1 (cont'd.)

Selection of Chemicals of Potential Concern in Soils [a]

Chemicals	Range of Hits (mg/kg)			Frequency of Detection	Range of Quantitation Limits		Reason for Exclusion as a COPC
Dimethylbenzene, 1,3- / m-Xyle		–		0 / 23	0.005 –	0.230	Not Detected
Dimethylphenol, 2,4-		–		0 / 28	0.300 –	3.000	Not Detected
Dinitroaniline, 2,6-		–		0 / 18	0.570 –	0.570	Not Detected
Dinitroaniline, 3,5-		–		0 / 18	1.600 –	1.600	Not Detected
Dinitrobenzene, 1,3-		–		0 / 4	0.504 –	0.504	Not Detected
Dinitrophenol, 2,4-		–		0 / 28	1.700 –	20.000	Not Detected
Dinitrotoluene, 2,4-		–		0 / 32	0.390 –	3.900	Not Detected
Dinitrotoluene, 2,6-		–		0 / 32	0.320 –	5.300	Not Detected
Diphenylhydrazine, 1,2-		–		0 / 18	0.520 –	0.520	Not Detected
Dithiane		–		0 / 28	0.065 –	2.400	Not Detected
Endosulfan sulfate		–		0 / 33	0.001 –	2.000	Not Detected
Endrin	0.013	–	0.500	11 / 34	0.007 –	1.300	
Endrin aldehyde		–		0 / 18	1.800 –	1.800	Not Detected
Endrin ketone		–		0 / 33	0.001 –	2.000	Not Detected
Ethylbenzene		–		0 / 23	0.003 –	0.190	Not Detected
Fluoranthene	0.132	–	54.100	21 / 28	0.520 –	5.200	See PAHs – high MW
Fluorene	0.159	–	1.050	7 / 28	0.065 –	3.000	See PAHs – low MW
Gamma-Chlordane	0.014	–	0.173	6 / 11	0.004 –	0.004	
Gamma-Hexachlorocyclohexane		–		0 / 34	0.001 –	0.100	Not Detected
HMX		–		0 / 4	2.000 –	2.000	Not Detected
Heptachlor	0.013	–	0.013	1 / 34	0.001 –	0.240	Below Screening Levels; low frequency of detection
Heptachlor epoxide	0.002	–	0.119	13 / 34	0.001 –	0.480	Only 1 value slightly above lowest SL
Hexachlorobenzene		–		0 / 28	0.080 –	2.600	Not Detected
Hexachlorobutadiene		–		0 / 28	0.420 –	4.200	Not Detected
Hexachlorocyclopentadiene		–		0 / 28	0.300 –	3.000	Not Detected
Hexachloroethane		–		0 / 28	0.400 –	4.000	Not Detected
Hexanone, 2-		–		0 / 23	0.010 –	1.000	Not Detected
Indeno (1,2,3-cd) pyrene	0.322	–	10.400	5 / 28	0.210 –	2.400	See PAHs – high MW
Isodrin	0.031	–	0.343	6 / 34	0.003 –	0.480	Below Screening Levels
Isophorone		–		0 / 28	0.300 –	3.000	Not Detected
Malathion		–		0 / 28	0.180 –	4.800	Not Detected
Methoxychlor	0.051	–	0.470	4 / 33	0.036 –	10.000	Only 1 value slightly above lowest SL
Methyl-4,6,dinitrophenol, 2-		–		0 / 28	0.800 –	20.000	Not Detected
Methyl-4-chlorophenol, 3-		–		0 / 28	0.300 –	3.000	Not Detected
Methylene chloride		–		0 / 23	0.005 –	4.400	Not Detected
Methylisobutyl ketone		–		0 / 23	0.010 –	0.630	Not Detected
Methylnaphthalene, 2-	0.064	–	0.323	7 / 28	0.032 –	3.000	Below Screening Levels
Methylphenol, 2-		–		0 / 28	0.098 –	3.000	Not Detected
Methylphenol, 4-		–		0 / 28	0.240 –	3.000	Not Detected
Mirex		–		0 / 18	0.140 –	0.140	Not Detected
N-Nitrosodi-N-propylamine		–		0 / 18	1.100 –	1.100	Not Detected
N-Nitrosodiphenylamine		–		0 / 28	0.300 –	3.000	Not Detected
N-Nitrosodiphenylamine		–		0 / 18	0.290 –	0.290	Not Detected
Naphthalene		–		0 / 28	0.420 –	4.200	Not Detected
Nitroaniline, 2-		–		0 / 28	1.700 –	20.000	Not Detected
Nitroaniline, 3-		–		0 / 28	1.700 –	20.000	Not Detected
Nitroaniline, 4-		–		0 / 28	1.700 –	20.000	Not Detected
Nitrobenzene		–		0 / 32	0.300 –	3.000	Not Detected
Nitrophenol, 2-		–		0 / 28	0.300 –	3.000	Not Detected
Nitrophenol, 4-		–		0 / 28	1.700 –	20.000	Not Detected
Nitrosodi-N-propylamine		–		0 / 10	0.360 –	3.600	Not Detected
Nitrotoluene, 3-		–		0 / 18	0.340 –	0.340	Not Detected
Oxathiane, 1,4-		–		0 / 28	0.075 –	2.500	Not Detected
PAHs – low molecular weight [b,d]	0.589	–	37.2	18 / 28	0.881 –	21.2	Below screening values
PAHs – high molecular weight [c,d]	2.64	–	275	24 / 28	3.88 –	38.8	
Parathion		–		0 / 28	0.460 –	4.600	Not Detected
PCB 1016		–		0 / 35	0.070 –	1.000	Not Detected
PCB 1221		–		0 / 24	0.100 –	1.900	Not Detected
PCB 1232		–		0 / 24	0.100 –	1.900	Not Detected
PCB 1242		–		0 / 24	0.100 –	1.900	Not Detected
PCB 1248		–		0 / 24	0.100 –	1.900	Not Detected
PCB 1254		–		0 / 24	0.048 –	3.800	Not Detected
PCB 1260	0.084	–	4.870	6 / 35	0.048 –	0.790	
PCB 1262		–		0 / 18	6.300 –	6.300	Not Detected
Pentachlorophenol		–		0 / 28	0.760 –	20.000	Not Detected
Phenanthrene	0.164	–	16.800	18 / 28	0.032 –	4.100	See PAHs – low MW
Phenol		–		0 / 28	0.052 –	3.000	Not Detected
Pyrene	0.148	–	52.600	24 / 28	0.420 –	4.200	See PAHs – high MW
RDX		–		0 / 4	1.280 –	1.280	Not Detected
Styrene		–		0 / 23	0.005 –	0.600	Not Detected
Supona		–		0 / 18	0.920 –	0.920	Not Detected
Tetrachloroethane, 1,1,2,2-		–		0 / 23	0.002 –	0.200	Not Detected
Tetrachloroethene	0.002	–	0.002	1 / 23	0.002 –	0.160	Below Screening Levels; low frequency of detection
TETRYL		–		0 / 4	2.110 –	2.110	Not Detected

Table A-1 (cont'd.)

Selection of Chemicals of Potential Concern in Soils [a]

Chemicals	Range of Hits (mg/kg)			Frequency of Detection	Range of Quantitation Limits			Reason for Exclusion as a COPC
Toluene	0.205	–	0.205	1 / 23	0.007	–	0.100	Below Screening Levels; low frequency of detection
Toxaphene		–		0 / 23	0.226	–	12.000	Not Detected
Trichlorobenzene, 1,2,3–		–		0 / 28	0.032	–	2.900	Not Detected
Trichlorobenzene, 1,2,4–		–		0 / 28	0.220	–	2.900	Not Detected
Trichloroethane, 1,1,1–		–		0 / 23	0.004	–	0.200	Not Detected
Trichloroethane, 1,1,2–		–		0 / 23	0.020	–	0.330	Not Detected
Trichloroethylene		–		0 / 23	0.004	–	0.230	Not Detected
Trichlorophenol, 2,4,5–		–		0 / 28	0.490	–	20.000	Not Detected
Trichlorophenol, 2,4,6–		–		0 / 28	0.061	–	20.000	Not Detected
Trifluorochloromethane		–		0 / 23	0.005	–	0.230	Not Detected
Trinitrobenzene, 1,3,5–		–		0 / 4	0.922	–	0.922	Not Detected
Trinitrotoluene, 2,4,6–		–		0 / 4	2.000	–	2.000	Not Detected
Vapona		–		0 / 18	0.068	–	0.068	Not Detected
Vinyl acetate		–		0 / 23	0.010	–	1.000	Not Detected
Vinyl chloride		–		0 / 23	0.010	–	1.800	Not Detected
Xylenes		–		0 / 13	0.780	–	0.780	Not Detected
Inorganics								
Aluminum	6680.000	–	24833.333	35 / 35		–		Within natural levels in lit. (although exceeds SLs)
Antimony		–		0 / 35	4.680	–	19.600	Not Detected
Arsenic	3.200	–	52.000	35 / 35		–		
Barium	24.000	–	302.933	35 / 35		–		Below Screening Levels
Beryllium	0.192	–	5.024	23 / 35	0.427	–	0.684	Below Screening Levels
Boron	10.600	–	10.600	1 / 3	7.370	–	7.370	Below Screening Levels
Cadmium	0.771	–	3.530	4 / 35	0.447	–	1.200	
Calcium	829.000	–	9820.000	35 / 35		–		Low toxicity; within natural levels in the lit.
Chromium	12.900	–	71.200	35 / 35		–		
Cobalt	5.090	–	89.300	35 / 35	1.500	–	1.500	Only one value marginally exceeds Screening Levels
Copper	22.550	–	1550.000	35 / 35		–		
Iron	1730.000	–	130000.000	35 / 35		–		Low toxicity; within natural levels in the lit.
Lead	37.800	–	521.000	33 / 34	54.700	–	54.700	
Magnesium	1730.000	–	8340.000	35 / 35		–		Low toxicity; within natural levels in the lit.
Manganese	197.000	–	1290.000	35 / 35		–		
Mercury	0.065	–	0.567	28 / 35	0.028	–	0.050	Below Screening Levels
Molybdenum		–		0 / 3	1.490	–	1.490	Not Detected
Nickel	12.200	–	99.200	35 / 35		–		
Potassium	486.000	–	3800.000	35 / 35		–		Below Screening Levels
Selenium		–		0 / 34	4.420	–	20.700	Not Detected
Silver	0.055	–	0.794	3 / 35	0.034	–	0.803	Below Screening Levels
Sodium	53.100	–	693.000	35 / 35		–		Below Screening Levels
Tellurium		–		0 / 3	5.480	–	5.480	Not Detected
Thallium		–		0 / 35	0.200	–	34.300	Not Detected
Tin	6.610	–	6.610	1 / 10	5.390	–	5.810	Low frequency of detection; within natural levels in the lit.
Uranium	0.151	–	0.151	1 / 10	0.108	–	0.119	Low frequency of detection; within natural levels in the lit.
Vanadium	23.700	–	126.767	35 / 35		–		Below Screening Levels
Zinc	53.800	–	849.000	35 / 35		–		
Cyanide	0.319	–	0.429	3 / 23	0.250	–	5.000	Below Screening Levels

[a] Chemicals of potential concern are identified in bold.
[b] Includes PAHs with 3 rings or less: acenaphthene, acenaphthylene, anthracene, fluorene, phenanthrene.
[c] Includes PAHs with greater than 3 rings: benzo(a)anthracene, benzo(a)pyrene, benzo(b)fluoranthene, benzo(k)fluoranthene, benzo(g,h,i)perylene, chrysene, dibenz(a,h)anthracene, fluoranthene, indeno(1,2,3–cd)pyrene, pyrene
[d] According to guidance from U.S. EPA Region I, PAHs were grouped into low and high MW categories based on similar modes of action.

COPC – Chemical of potential concern
lit. – Literature
MW – Molecular weight
PAHs – Polychlorinated aromatic hydrocarbons
SL – Screening level

Table A–2

Preliminary Screening Values
for the Northern Short–Tailed Shrew

Chemical	Screening Values Based on Soil Ingestion (mg/kg)	Screening Values Based on Earthworm Ingestion (mg/kg)
Organics		
Acetone	9.31E+03	NC
Aldrin	5.17E−01	1.62E−02
Benzene	1.66E+01	NC
Benzyl alcohol	8.28E+01	NC
2–Butanone	1.81E+04	NC
Butyl benzyl phthalate	6.21E+01	NC
Chlordane	1.34E+00	2.79E−02
DDD	2.48E+02	3.10E+00
DDE	4.55E+01	6.37E−01
DDT	1.03E+01	1.01E−01
Dieldrin	3.41E+00	3.57E−02
beta–Endosulfan	8.79E−01	NC
Endrin	2.59E+00	7.44E−02
Heptachlor	5.17E−01	NC
Heptachlor epoxide	2.59E+00	8.93E−02
gamma–HCCH	3.41E+00	3.49E−02
Isodrin	4.81E−01	NC
Methoxychlor	1.24E+02	4.59E−01
2–Methyl naphthalene	3.47E+02	NC
PAHs		
Low MW [a]	2.59E+02	1.01E+02
High MW [b]	2.07E+00	6.53E−01
PCB (Aroclor 1260)	7.24E+01	3.41E−01
Tetrachloroethene	1.14E+02	NC
Toluene	2.28E+02	NC
Inorganics		
Aluminum	8.28E+02	2.52E+02
Arsenic	1.97E+00	4.24E+00
Barium	1.91E+03	5.51E+02
Beryllium	5.69E+00	NC
Boron	1.81E+02	NC
Cadmium	1.71E+01	3.84E−01
Chromium	9.31E+00	1.25E+00
Cobalt	5.17E+01	NC
Copper	2.69E+03	6.33E+02
Cyanide	1.14E+02	NC
Lead	4.76E+01	9.30E+00
Manganese	2.90E+02	2.73E+02
Mercury	3.26E+02	9.25E+01
Nickel	1.45E+00	8.33E−02
Potassium	3.47E+03	NC
Selenium	3.88E+00	NC
Silver	2.07E+02	NC
Sodium	1.03E+04	NC
Tin	NC	NC
Uranium	NC	NC
Vanadium	1.76E+02	NC
Zinc	1.03E+03	1.08E+01

Table A-3

Model for Calculating Screening Levels for the Northern Short-Tailed Shrew Based on the Incidental Ingestion of Soil

$$\text{Screening Level (SL) for Soil Ingestion (mg/kg)} = \frac{RTV \times BW \times CF}{SIR \times FI}$$

Where:

SL	=	Screening level based on soil ingestion (mg/kg)
RTV	=	Reference toxicity value (mg/kg-day)
SIR	=	Soil ingestion rate (g dry weight/day)
FI	=	Fraction ingested from contaminated source (unitless)
BW	=	Body weight (kg)
CF	=	Conversion factor (g/kg)
Exposure Assumptions		
SL	=	Screening levels are presented in Table A-2
RTV	=	Reference toxicity values are presented in Table A-6
SIR	=	0.29 g dry weight/day[a]
FI	=	1[b]
BW	=	0.015 kg (EPA, 1993)
CF	=	1000 g/kg

[a]Assumed to be 10.4% of food intake (EPA, 1993).
[b]Assumes home range of the shrew falls within the site area.

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Table A-4

Model for Calculating Screening Levels for the Northern Short-Tailed Shrew Based on the Ingestion of Earthworms

$$\text{Screening Level (SL) for Earthworm Ingestion (mg/kg)} = \frac{RTV \times BW \times CF}{BAF \times IR \times FI}$$

Where:

SL	=	Screening level based on earthworm ingestion (mg/kg)
RTV	=	Reference toxicity value (mg/kg-day)
BAF	=	Soil-to-earthworm bioaccumulation factor (unitless)
IR	=	Earthworm ingestion rate (g dry weight/day)
FI	=	Fraction ingested from contaminated source (unitless)
BW	=	Body weight (kg)
CF	=	Conversion factor (g/kg)

Exposure Assumptions

SL	=	Screening levels are presented in Table A-2
RTV	=	Reference toxicity values are presented in Table A-6
BAF	=	Bioaccumulation factors are presented in Table A-5
IR	=	2.8 g dry weight/day (EPA, 1993)
FI	=	1[a]
BW	=	0.015 kg (EPA, 1993)
CF	=	1000 g/kg

[a]Assumes home range of the shrew falls within the site area.

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Table A-5

Earthworm Bioaccumulation Factors (BAFs) for Screening the Chemicals of Potential Concern

Chemical	Bioaccumulation Factor[a]	Reference
Organics		
Acetone	NA	----
Aldrin	3.30E+00	Gish, 1970
Benzene	NA	----
Benzyl alcohol	NA	----
2-Butanone	NA	----
Butyl benzyl phthalate	NA	----
Chlordane	5.00E+00	Gish, 1970
DDD	8.30E+00	Gish, 1970
DDE	7.40E+00	Gish, 1970
DDT	1.06E+01	Gish, 1970
Dieldrin	9.90E+00	Gish, 1970
beta-Endosulfan	NA	----
Endrin	3.60E+00	Gish, 1970
Heptachlor	NA	----
Heptachlor epoxide	3.00E+00	Gish, 1970
gamma-HCCH	1.01E+01	Wheatley and Hardman, 1968
Isodrin	NA	----
Methoxychlor	.280E+01	Thompson, 1973
2-Methyl naphthalene	NA	----
PAHs		
Acenaphthene	3.00E-01	Beyer and Stafford, 1993
Acenaphthylene	2.20E-01	Beyer and Stafford, 1993
Anthracene	3.20E-01	Beyer and Stafford, 1993
Benzo(a)anthracene	2.70E-01	Beyer and Stafford, 1993
Benzo(a)pyrene	3.40E-01	Beyer and Stafford, 1993
Benzo(b)fluoranthene	2.10E-01	Beyer and Stafford, 1993
Benzo(g,h,i)perylene	1.50E-01	Beyer and Stafford, 1993
Benzo(k)fluoranthene	2.10E-01	Beyer and Stafford, 1993

Table A-5

Earthworm Bioaccumulation Factors (BAFs) for Screening the Chemicals of Potential Concern (Continued)

Chemical	Bioaccumulation Factor[a]	Reference
Chrysene	4.40E-01	Beyer and Stafford, 1993
Dibenz(a,h)anthracene	4.90E-01	Beyer and Stafford, 1993
Fluoranthene	3.70E-01	Beyer and Stafford, 1993
Fluorene	2.00E-01	Beyer and Stafford, 1993
Indeno(1,2,3-cd)pyrene	4.10E-01	Beyer and Stafford, 1993
Phenanthrene	2.80E-01	Beyer and Stafford, 1993
Pyrene	3.90E-01	Beyer and Stafford, 1993
PCB (Aroclor 1260)	2.20E+01	Diercxsens et al., 1985
Tetrachloroethene	NA	----
Toluene	NA	----
Inorganics		
Aluminum	3.40E-01	Beyer and Stafford, 1993
Arsenic	4.80E-02	Beyer and Cromartie, 1987
Barium	3.60E-01	Beyer and Stafford, 1993
Beryllium	NA	----
Boron	NA	----
Cadmium	4.60E+00	Beyer and Stafford, 1993
Chromium	7.70E-01	Beyer and Cromartie, 1987
Cobalt	NA	----
Copper	4.40E-01	Beyer and Cromartie, 1987
Cyanide	NA	----
Lead	5.30E-01	Beyer and Cromartie, 1987
Manganese	1.10E-01	Kabata-Pendias and Pendias, 1984
Mercury	3.65E-01	Kabata-Pendias and Pendias, 1984
Nickel	1.80E+00	Kabata-Pendias and Pendias, 1984
Potassium	NA	----
Selenium	NA	----
Silver	NA	----

Table A-5

Earthworm Bioaccumulation Factors (BAFs) for Screening the Chemicals of Potential Concern (Continued)

Chemical	Bioaccumulation Factor[a]	Reference
Sodium	NA	----
Tin	NA	----
Uranium	NA	----
Vanadium	NA	----
Zinc	9.90E+00	Beyer and Cromartie, 1987

[a]Reported on a dry weight basis.

Table A-6

Basis of the Shrew Reference Toxicity Values (RTVs)
(mg/kg-day)

Chemical	Species	Toxicity Endpoint	Effect	Dose (mg/kg-day)	Reference	Applied Safety Factor [c]	Shrew RTVs (mg/kg-day)
Organics							
Acetone	Rat	Chronic NOAEL	No effect on spermatogenesis	9.00E+02	Dietz et al., 1991	5	1.8E+02
Aldrin	Rat	Chronic Effect Dose	Nephritis in females	2.50E-01	Reuber, 1980	25	1.0E-02
Benzene	Mouse	Chronic Effect Dose	Immunotoxic effects/severe anemia	8.00E+00	Hsieh et al., 1988	25	3.2E-01
Benzyl alcohol	Rat	Acute LD_{50}	Mortality	1.23E+03	RTECS, 1993	750	1.6E+00
2-Butanone	Rat	Chronic NOAEL	No effect on pup survival	1.77E+03	Cox et al., 1975	5	3.5E+02
Butyl benzyl phthalate	Mouse	Acute NOAEL	No maternal or fetotoxicity	1.82E+02	NTP, 1990	150	1.2E+00
Chlordane	Mouse	Chronic NOAEL	No significant liver lesions	1.30E-01	Khasawinah and Grutsch, 1989	5	2.6E-02
DDD	Rat	Chronic Effect Dose	Decreased organ/body weight;suppressed immunity	1.21E+02	Hamid et al., 1974	25	4.8E+00
DDE	Rat	Chronic Effect Dose	Mortality associated with tumor growth	2.19E+01	NCI, 1978	25	8.8E-01
DDT	Rat	Chronic NOAEL	No growth effect on pups	1.00E+00	Clement et al., 1974	5	2.0E-01
Dieldrin	Mouse	Chronic NOAEL	No significant pup mortality	3.30E-01	Virgo and Bellward, 1975	5	6.6E-02
beta-Endosulfan	Rat	Acute NOAEL	No liver enzyme induction	2.50E+00	Den Tonkelaar and Van Esch, 1974	150	1.7E-02
Endrin	Rat	Chronic NOAEL	No significant mortality	2.50E-01	Treon et al., 1955	5	5.0E-02
Heptachlor	Rat	Chronic Effect Dose	16% embryo survival, decreased fertility	2.50E-01	Green, 1970	25	1.0E-02
Heptachlor epoxide	Rat	Chronic NOAEL	No effects	2.50E-01	Dow Chemical Co., 1959	5	5.0E-02
gamma-HCCH	Rat	Chronic NOAEL	No liver/kidney toxicity	3.30E-01	Zoecon Corp., 1983	5	6.6E-02
Isodrin	Rat	LD50	Mortality	7.00E+00	Sax, 1984	750	9.3E-03
Methoxychlor	Rat	Chronic Effect Dose	Reduced fertility, late onset of puberty	6.00E+01	Harris et al., 1974	25	2.4E+00
2-Methyl naphthalene	Rat	LDlo	Mortality	5.00E+03	Sax, 1984	750	6.7E+00
PAHs							
Low MW [a]	Mouse	Chronic NOAEL	No decrease in RBC, packed cell vol., or hemoglobin	1.25E+02	IRIS, 1995	5	2.5E+01
High MW [b]	Mouse	Chronic LOAEL	Impaired fertility	1.00E+01	Opresko et al., 1994	25	4.0E-01
PCB (Aroclor 1260)	Rat	Chronic NOAEL	No reproductive effect	6.90E+00	Linder et al., 1974	5	1.4E+00
Tetrachloroethene	Rat	Chronic LOAEL	Decreased BW in females, incr. organ to BW ratio	5.60E+01	Hayes et al., 1986	25	2.2E+00
Toluene	Mouse	Chronic NOAEL	No effect on immune function	2.20E+01	Hsieh et al., 1989	5	4.4E+00
Inorganics							
Aluminum	Rat (male)	Chronic No Effect Dose	No reproductive abnormalities	7.75E+01	Dixon et al., 1979	5	1.6E+01
Arsenic	Mouse	Chronic Effect Dose	Decreased survival in males	9.50E-01	Schroeder and Balassa, 1967	25	3.8E-02
Barium	Mouse	Chronic NOAEL	No significant mortality or behavioral effects	1.83E+02	Dietz et al., 1992	5	3.7E+01
Beryllium	Rat	Chronic NOAEL	No adverse effects	5.40E-01	IRIS, 1995	5	1.1E-01
Boron	Rat	Chronic NOAEL	No testicular/ovarian effects	1.75E+01	Weir and Fisher, 1972	5	3.5E+00
Cadmium	Rat	Chronic NOAEL	No effect on motor or kidney function	1.64E+00	Kotsonis and Klaassen, 1978	5	3.3E-01
Chromium	Mouse	Chronic Effect Dose	Decreased spermatogenesis	4.57E+00	Zahid et al., 1990	25	1.8E-01
Cobalt	Rat	Chronic NOAEL	No testicular atrophy	5.00E+00	Nation et al., 1983	5	1.0E+00
Copper	Mouse	Chronic NOAEL	No reproductive effects	2.60E+02	Lecyk, 1980	5	5.2E+01
Cyanide	Rat	Chronic NOAEL	No weight loss, thyroid effects, or myelin degener.	1.08E+01	Howard and Hanzel, 1955	5	2.2E+00
Lead	Rat	Chronic NOAEL	No depressed immunity	4.60E+00	Luster et al., 1978	5	9.2E-01
Manganese	Rat	Chronic Effect Dose	Motor ability, aggressive behavior	1.40E+02	Chandra, 1983	25	5.6E+00
Mercury	Rat	Chronic NOAEL	Kidney enlargement	3.15E+01	Fitzhugh et al., 1950	5	6.3E+00
Nickel	Rat	Chronic Effect Dose	Increased number of young deaths and runts	7.00E-01	Schroeder and Mitchener, 1971	25	2.8E-02
Potassium	Rat	Acute NOAEL	No effects	1.00E+04	Drescher et al., 1958	150	6.7E+01
Selenium	Mouse	Chronic NOAEL	No effects on fetal growth	3.75E-01	Nobunaga et al., 1979	5	7.5E-02
Silver	Rat	Chronic No Effect Dose	No effects	2.00E+01	Walker, 1971	5	4.0E+00
Sodium	Rat	Chronic NOAEL	Increased mortality	1.00E+03	Meneely and Ball, 1958	5	2.0E+02
Tin	NDA	---	---	---	---	---	---
Uranium	NDA	---	---	---	---	---	---
Vanadium	Mouse	Chronic NOAEL	No decreased motility, fertility	1.68E+01	Llobet et al., 1993	5	3.4E+00
Zinc	Rat	Chronic NOAEL	No reproductive effects	1.00E+02	Schlicker and Cox, 1968	5	2.0E+01

[a] Based on fluorene
[b] Based on benzo(a)pyrene
[c] See Table A-7

Table A-7

Safety Factors Used to Derive Screening Reference Toxicity Values for Terrestrial Target Organisms

Available Toxicity Endpoint	Target Toxicity Endpoint	Safety Factor
Acute LOAEL	Acute NOAEL	5
Acute NOAEL	Chronic NOAEL	30 *
Chronic LOAEL	Chronic NOAEL	5
Within Phylogenetic Class Sensitivity (i.e., different species but same class)	Target Species Toxicity	5

* From Ford, 1992. This extrapolation from acute to chronic effects is included only to develop RTVs for screening purposes, in order to prevent screening out chemicals for which only acute data are available. However, because of the uncertainty associated with this extrapolation, it was not used to develop RTVs in the risk estimation.

For example, in developing a reference toxicity value for a short-tailed shrew when the only data available is an acute LOAEL for a rat, the following steps would be taken:

Rat acute LOAEL for Compound X = 600 mg/kg.

(1) Acute LOAEL → Acute NOAEL

$$\frac{600\ mg/kg}{5} = 120\ mg/kg$$

(2) Acute NOAEL → Chronic NOAEL

$$\frac{120\ mg/kg}{30} = 4\ mg/kg$$

(3) Within Phylogenetic Class → Target Species Screening RTV

$$\frac{4\ mg/kg}{5} = 0.8\ mg/kg$$

Table A-8

Background Concentrations of Metals in U.S. Soils (mg/kg)

Chemical	Eastern U.S. Soils[a]		U.S. Various Soils[b]		New Jersey Soils[c] All areas Arithmetic Mean	New Jersey Soils[c] Urban areas Arithmetic Mean
	Range	Arithmetic Mean	Range	Mean		
Aluminum	7000 – >100,000	57000	NDA	NDA	NDA	NDA
Arsenic	<0.1– 73	7.4	<1– 93.2	7	5.38	8.26
Cadmium	NDA	NDA	0.41 – 1.5	NDA	0.37	0.65
Calcium	100 – 280000	6300	NDA	NDA	NDA	NDA
Chromium	1 – 1000	52	7 – 1500	50	12.3	12.06
Copper	<1– 700	22	3 – 300	26	17.2	42.2
Iron	100 – >100000	25000	5000 – 50000	NDA	NDA	NDA
Lead	<10– 300	17	<10– 70	26	58.4	177.71
Magnesium	50 – 50000	4600	NDA	NDA	NDA	NDA
Manganese	<2– 7000	640	20 – 3000	490	261	334
Nickel	<5– 700	18	<5– 150	18.5	10.3	16.56
Tin	<0.1– 10	1.5	<0.1– 7.7	0.6 – 1.7	NDA	NDA
Uranium	0.29 – 11	2.7	0.3 – 10.7	3.7	NDA	NDA
Zinc	<5– 2900	52	10 – 300	73.5	73.4	127.5

NDA – No data available

Sources:

[a] Shacklette and Boerngen, 1984

[b] Kabata–Pendias and Pendias, 1984

[c] NJDEPE, 1992

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APPENDIX B

CALCULATION OF CHEMICAL CONCENTRATIONS IN EARTHWORMS

Appendix B
Calculation of Chemical Concentrations in Earthworms

Calculation of chemical concentrations in earthworms were determined by multiplying chemical-specific bioaccumulation factors (BAFs) by chemical concentrations found in soils. Accumulation of chemicals in earthworms is dependent on numerous site-specific factors: soil type, pH, soil organic content, and earthworm species. When two or more BAFs were available for a specific chemical, the BAF determined at conditions most similar to those at the site was selected. If experimental soil conditions were unavailable for comparison to known soil conditions, then an average BAF for a given chemical at soil concentrations similar to those found at the site was selected (Beyer and Cromartie, 1987). BAFs were calculated in the experimental studies by dividing the concentration detected in the earthworm by the concentration measured in soil; the ratio is expressed as follows:

$$BAF = \frac{Earthworm\ concentration}{Soil\ concentration}$$

The ingestion rates used for birds and mammals are in dry weight (*i.e.*, grams dry weight diet/day); therefore, BAFs which were calculated based on earthworm and soil wet weight have been converted to dry weight by multiplying wet weight BAFs by 4 (Beyer and Gish, 1980). The chemical-specific BAFs and their sources are presented in Table B-1. The estimated earthworm concentrations are presented in Table B-2.

Table B-1
Earthworm Bioaccumulation Factors (BAFs) for the Chemicals of Potential Concern

Chemical	Bioaccumulation Factor[a]	Reference
Organics		
Chlordane	5.00E+00	Gish, 1970
DDD	8.30E+00	Gish, 1970
DDE	7.40E+00	Gish, 1970
DDT	1.06E+01	Gish, 1970
Dieldrin	9.90E+00	Gish, 1970
Endrin	3.60E+00	Gish, 1970
PAHs		
Benzo(a)anthracene	2.70E-01	Beyer and Stafford, 1993
Benzo(a)pyrene	3.40E-01	Beyer and Stafford, 1993
Benzo(b)fluoranthene	2.10E-01	Beyer and Stafford, 1993
Benzo(g,h,i)perylene	1.50E-01	Beyer and Stafford, 1993
Benzo(k)fluoranthene	2.10E-01	Beyer and Stafford, 1993
Chrysene	4.40E-01	Beyer and Stafford, 1993
Dibenz(a,h)anthracene	4.90E-01	Beyer and Stafford, 1993
Fluoranthene	3.70E-01	Beyer and Stafford, 1993
Indeno(1,2,3-cd)pyrene	4.10E-01	Beyer and Stafford, 1993
Pyrene	3.90E-01	Beyer and Stafford, 1993
PCB (Aroclor 1260)	2.20E+01	Diercxsens et al., 1985
Inorganics		
Arsenic	4.80E-02	Beyer and Cromartie, 1987
Cadmium	4.60E+00	Beyer and Stafford, 1993
Chromium	7.70E-01	Beyer and Cromartie, 1987
Copper	4.40E-01	Beyer and Cromartie, 1987
Lead	5.30E-01	Beyer and Cromartie, 1987
Manganese	1.10E-01	Kabata-Pendias and Pendias, 1984
Nickel	1.80E+00	Kabata-Pendias and Pendias, 1984
Zinc	9.90E+00	Beyer and Cromartie, 1987

[a]Reported on a dry weight basis.

Table B-2

Estimation of Earthworm Concentrations

Chemical	Soil Concentration (mg/kg)		BAF [a]	Earthworm Concentration [a] (mg/kg)	
	Mean	95 UCL		Mean	95 UCL
Organics					
Chlordane	1.67E+00	5.64E+00	5.00E+00	8.35E+00	2.82E+01
DDD	2.41E−01	8.19E−01	8.30E+00	2.00E+00	6.80E+00
DDE	5.61E−01	2.57E+00	7.40E+00	4.15E+00	1.90E+01
DDT	8.01E−01	4.61E+00	1.06E+01	8.49E+00	4.89E+01
Dieldrin	3.43E−02	9.67E−02	9.90E+00	3.40E−01	9.57E−01
Endrin	2.70E−01	5.00E−01	3.60E+00	9.72E−01	1.80E+00
PAHs					
Benzo(a)anthracene	2.33E+00	7.83E+00	2.70E−01	6.29E−01	2.11E+00
Benzo(a)pyrene	2.62E+00	3.63E+00	3.40E−01	8.91E−01	1.23E+00
Benzo(b)fluoranthene	1.72E+00	3.94E+00	2.10E−01	3.61E−01	8.27E−01
Benzo(g,h,i)perylene	1.53E+00	4.44E+00	1.50E−01	2.30E−01	6.66E−01
Benzo(k)fluoranthene	2.30E+00	6.06E+00	2.10E−01	4.83E−01	1.27E+00
Chrysene	2.36E+00	1.31E+01	4.40E−01	1.04E+00	5.76E+00
Dibenz(a,h)anthracene	3.75E−01	4.65E−01	4.90E−01	1.84E−01	2.28E−01
Fluoranthene	3.57E+00	5.55E+00	3.70E−01	1.32E+00	2.05E+00
Indeno(1,2,3−cd)pyrene	1.87E+00	4.09E+00	4.10E−01	7.67E−01	1.68E+00
Pyrene	4.17E+00	7.01E+00	3.90E−01	1.63E+00	2.73E+00
PCB (Aroclor 1260)	3.15E−01	4.96E−01	2.20E+01	6.93E+00	1.09E+01
Inorganics					
Arsenic	1.39E+01	1.69E+01	4.80E−02	6.67E−01	8.11E−01
Cadmium	6.92E−01	8.09E−01	4.60E+00	3.18E+00	3.72E+00
Chromium	2.40E+01	2.68E+01	7.70E−01	1.85E+01	2.06E+01
Copper	1.00E+02	1.01E+02	4.40E−01	4.40E+01	4.44E+01
Lead	2.13E+02	2.91E+02	5.30E−01	1.13E+02	1.54E+02
Manganese	3.90E+02	4.41E+02	1.10E−01	4.29E+01	4.85E+01
Nickel	2.86E+01	3.38E+01	1.80E+00	5.15E+01	6.08E+01
Zinc	1.38E+02	1.57E+02	9.90E+00	1.37E+03	1.55E+03

[a] Expressed in dry weight

APPENDIX C

CALCULATION OF CHEMICAL CONCENTRATIONS IN SEEDS

Appendix C
Calculation of Chemical Concentrations in Seeds

Chemical concentrations in seeds resulting from the uptake of chemicals from the soil were calculated using the following equation:

$$C_{seed} = C_{soil} \times PUF$$

Where:

C_{seed}	=	Chemical concentration in seed (mg/kg dry weight seed)
C_{soil}	=	Chemical concentration in soil (mg/kg dry weight soil)
PUF	=	Plant uptake factor (chemical-specific factor; unitless)

Plant uptake factors (PUFs) for organics were estimated using the relationship presented by Travis and Arms (1988):

$$PUF = 38.7 \times Kow^{-0.578}$$

Where:

PUF	=	Plant uptake factor (chemical-specific; unitless)
Kow	=	Octanol-water partition coefficient (chemical-specific)

For inorganics, transfer coefficients developed by Baes et al. (1984) for reproductive portions of plants were used to calculate concentrations of inorganic chemicals in seeds. These inorganic transfer coefficients are based on one or more of the following: analysis of literature, correlations with other parameters, elemental systematics, and comparisons of predicted with observed elemental concentrations in foods. The PUFs are reported in dry weight. The chemical-specific PUFs, Kows, and their sources are presented in Table C-1. The estimated plant seed concentrations are presented in Table C-2.

Table C-1
Plant Uptake Factors for the Chemicals of Potential Concern

Chemical	Plant Uptake Factor[a]	Log Kow	Reference
Organics			
Chlordane	9.57E-01	2.78	EPA, 1987c
DDD	1.34E-02	5.99	EPA, 1992c
DDE	2.16E-02	5.63	EPA, 1987c
DDT	5.77E-02	4.89	EPA, 1987c
Dieldrin	3.48E-01	3.54	EPA, 1987c
Endrin	3.48E-01	3.54	EPA, 1987c
PAHs			
Benzo(a)anthracene	2.21E-02	5.61	EPA, 1987c
Benzo(a)pyrene	1.77E-01	4.05	EPA, 1987c
Benzo(b)fluoranthene	1.22E-02	6.06	EPA, 1987c
Benzo(g,h,i)perylene	6.68E-03	6.51	EPA, 1987c
Benzo(k)fluoranthene	1.22E-02	6.06	EPA, 1987c
Chrysene	2.21E-02	5.61	EPA, 1987c
Dibenz(a,h)anthracene	1.37E-02	5.97	EPA, 1987c
Fluoranthene	5.70E-02	4.90	EPA, 1987c
Indeno(1,2,3-cd)pyrene	6.68E-03	6.51	EPA, 1987c
Pyrene	5.85E-02	4.88	EPA, 1987c
PCB (Aroclor 1260)	1.14E-02	6.11	EPA, 1987c
Inorganics			
Arsenic	6.00E-03	NA	Baes et al., 1984
Cadmium	1.50E-01	NA	Baes et al., 1984
Chromium	4.50E-03	NA	Baes et al., 1984
Copper	2.50E-01	NA	Baes et al., 1984
Lead	9.00E-03	NA	Baes et al., 1984
Manganese	5.00E-02	NA	Baes et al., 1984
Nickel	6.00E-02	NA	Baes et al., 1984
Zinc	9.00E-01	NA	Baes et. al., 1984

[a]Reported on a dry weight basis.
NA - Not applicable

Table C–2

Estimation of Seed Concentrations

Chemical	Soil Concentration (mg/kg)		PUF [a]	Seed Concentration [a] (mg/kg)	
	Mean	95 UCL		Mean	95 UCL
Organics					
Chlordane	1.67E+00	5.64E+00	9.57E−01	1.60E+00	5.40E+00
DDD	2.41E−01	8.19E−01	1.34E−02	3.23E−03	1.10E−02
DDE	5.61E−01	2.57E+00	2.16E−02	1.21E−02	5.55E−02
DDT	8.01E−01	4.61E+00	5.77E−02	4.62E−02	2.66E−01
Dieldrin	3.43E−02	9.67E−02	3.48E−01	1.19E−02	3.37E−02
Endrin	2.70E−01	5.00E−01	3.48E−01	9.40E−02	1.74E−01
PAHs					
Benzo(a)anthracene	2.33E+00	7.83E+00	2.21E−02	5.15E−02	1.73E−01
Benzo(a)pyrene	2.62E+00	3.63E+00	1.77E−01	4.64E−01	6.43E−01
Benzo(b)fluoranthene	1.72E+00	3.94E+00	1.22E−02	2.10E−02	4.81E−02
Benzo(g,h,i)perylene	1.53E+00	4.44E+00	6.68E−03	1.02E−02	2.97E−02
Benzo(k)fluoranthene	2.30E+00	6.06E+00	1.22E−02	2.81E−02	7.39E−02
Chrysene	2.36E+00	1.31E+01	2.21E−02	5.22E−02	2.90E−01
Dibenz(a,h)anthracene	3.75E−01	4.65E−01	1.37E−02	5.14E−03	6.37E−03
Fluoranthene	3.57E+00	5.55E+00	5.70E−02	2.03E−01	3.16E−01
Indeno(1,2,3−cd)pyrene	1.87E+00	4.09E+00	6.68E−03	1.25E−02	2.73E−02
Pyrene	4.17E+00	7.01E+00	5.85E−02	2.44E−01	4.10E−01
PCB (Aroclor 1260)	3.15E−01	4.96E−01	1.14E−02	3.59E−03	5.65E−03
Inorganics					
Arsenic	1.39E+01	1.69E+01	6.00E−03	8.34E−02	1.01E−01
Cadmium	6.92E−01	8.09E−01	1.50E−01	1.04E−01	1.21E−01
Chromium	2.40E+01	2.68E+01	4.50E−03	1.08E−01	1.21E−01
Copper	1.00E+02	1.01E+02	2.50E−01	2.50E+01	2.53E+01
Lead	2.13E+02	2.91E+02	9.00E−03	1.92E+00	2.62E+00
Manganese	3.90E+02	4.41E+02	5.00E−02	1.95E+01	2.21E+01
Nickel	2.86E+01	3.38E+01	6.00E−02	1.72E+00	2.03E+00
Zinc	1.38E+02	1.57E+02	9.00E−01	1.24E+02	1.41E+02

[a] Expressed in dry weight

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APPENDIX D

BIRD SURVEY FOR THE AMTL SITE VICINITY

MASSACHUSETTS AUDUBON SOCIETY, LINCOLN, MASS. 01773

a checklist of MASSACHUSETTS BIRDS

Observed by Robert H. Stymeist
94 GROVE ST. WATERTOWN MA 02172
617 926-3603 (617) 923-3139

Total Number of Birds Checked ______ Year ______

WATERTOWN MASS

ARSENAL PROPERTY * = BREEDING M = MIGRANT - SPRING/FALL

Name of Species	Locality	Date Seen	Name of Species	Locality	Date Seen
Red-throated Loon			Green-winged Teal		
Common Loon			American Black Duck	UNCOMMON	
Pied-billed Grebe	Winter visitor - esp. when ponds frozen		Mallard *	VERY COMMON - BREEDER	
Horned Grebe			Northern Pintail		
Red-necked Grebe			Blue-winged Teal		
Northern Fulmar			Northern Shoveler		
Cory's Shearwater			Gadwall		
Greater Shearwater			Eurasian Wigeon		
Sooty Shearwater			American Wigeon		
Manx Shearwater			Canvasback		
Wilson's Storm-Petrel			Redhead		
Leach's Storm-Petrel			Ring-necked Duck	UNCOMMON IN WINTER	
Northern Gannet			Greater Scaup		
Great Cormorant			Lesser Scaup		
Double-crested Cormorant	COMMON APRIL - OCT		Common Eider		
American Bittern			King Eider		
Least Bittern			Harlequin Duck		
Great Blue Heron	UNCOMMON THROUGHOUT		Oldsquaw		
Great Egret			Black Scoter		
Snowy Egret			Surf Scoter		
Little Blue Heron			White-winged Scoter		
Tricolored Heron			Common Goldeneye		
Cattle Egret			Barrow's Goldeneye		
Green-backed Heron	UNCOMMON MAY-SEPT		Bufflehead	UNCOMMON IN WINTER	
Black-crowned Night-Heron	VERY COMMON LATE MAY-JULY		Hooded Merganser	COMMON FROM OCT-FEB	
Yellow-crowned Night-Heron			Common Merganser	COMMON	
Glossy Ibis			Red-breasted Merganser	UNCOMMON TO RARE WINTER	
Mute Swan			Ruddy Duck		
Snow Goose			Turkey Vulture		
Brant			Osprey	SPRING + FALL SEEN ONLY A FEW TIMES	
Canada Goose *	BREEDER		Bald Eagle		
Wood Duck	UNCOMMON IN WINTER		Northern Harrier		

ARSENAL - 2001

Name of Species	Locality	Date Seen	Name of Species	Locality	Date Seen
Sharp-shinned Hawk	OCCASIONAL FALL WINTER		Baird's Sandpiper		
Cooper's Hawk	RARE		Pectoral Sandpiper		
Northern Goshawk			Purple Sandpiper		
Red-shouldered Hawk			Dunlin		
Broad-winged Hawk			Stilt Sandpiper		
Red-tailed Hawk	FAIRLY COMMON THR.		Buff-breasted Sandpiper		
Rough-legged Hawk			Ruff		
American Kestrel	OCCASIONAL-ESP WINTER		Short-billed Dowitcher		
Merlin			Long-billed Dowitcher		
Peregrine Falcon			Common Snipe		
Ring-necked Pheasant			American Woodcock		
Ruffed Grouse			Wilson's Phalarope		
Wild Turkey			Red-necked Phalarope		
Northern Bobwhite			Red Phalarope		
Clapper Rail			Pomarine Jaeger		
King Rail			Parasitic Jaeger		
Virginia Rail			Laughing Gull		
Sora			Little Gull		
Common Moorhen			Common Black-headed Gull		
American Coot	UNCOMMON IN WINTER		Bonaparte's Gull		
Black-bellied Plover			Ring-billed Gull	COMMON THR.	
Lesser Golden-Plover			Herring Gull	COMMON THR	
Semipalmated Plover			Iceland Gull		
Piping Plover			Lesser Black-backed Gull		
Killdeer			Glaucous Gull		
American Oystercatcher			Great Black-backed Gull	COMMON THR	
Greater Yellowlegs			Black-legged Kittiwake		
Lesser Yellowlegs			Caspian Tern		
Solitary Sandpiper			Royal Tern		
Willet			Roseate Tern		
Spotted Sandpiper	UNCOMMON MAY-SEPT		Common Tern		
Upland Sandpiper			Arctic Tern		
Whimbrel			Forster's Tern		
Hudsonian Godwit			Least Tern		
Marbled Godwit			Black Tern		
Ruddy Turnstone			Black Skimmer		
Red Knot			Dovekie		
Sanderling			Thick-billed Murre		
Semipalmated Sandpiper			Razorbill		
Western Sandpiper			Black Guillemot		
Least Sandpiper			Rock Dove *	VERY COMMON THR	BREEDER
White-rumped Sandpiper			Mourning Dove *	COMMON THR	✓

Name of Species	Locality	Date Seen
Black-billed Cuckoo		
Yellow-billed Cuckoo		
Common Barn-Owl		
Eastern Screech-Owl	OCCASIONAL	
Great Horned Owl		
Snowy Owl		
Barred Owl		
Long-eared Owl		
Short-eared Owl		
Northern Saw-whet Owl		
Common Nighthawk	UNCOMMON FALL MIGRANT	
Chuck-will's-widow		
Whip-poor-will		
Chimney Swift Breeder *	FAIRLY COMMON MAY-SEPT	
Ruby-throated Hummingbird		
Belted Kingfisher *	UNCOMMON THROUGHOUT	
Red-headed Woodpecker		
Red-bellied Woodpecker		
Yellow-bellied Sapsucker		
Downy Woodpecker *	COMMON THR- BREEDER	
Hairy Woodpecker	UNCOMMON	
Northern Flicker *	FAIRLY COMMON - BREEDER	
Pileated Woodpecker		
Olive-sided Flycatcher		
Eastern Wood-Pewee		
Yellow-bellied Flycatcher		
Acadian Flycatcher		
Alder Flycatcher		
Willow Flycatcher		
Least Flycatcher		
Eastern Phoebe *	UNCOMMON BREEDER	
Great Crested Flycatcher		
Western Kingbird		
Eastern Kingbird *	UNCOMMON BREEDER	
Horned Lark		
Purple Martin		
Tree Swallow	UNCOMMON MAY-SEPT	
N. Rough-winged Swallow *	UNCOMMON BREEDER	
Bank Swallow		
Cliff Swallow		
Barn Swallow	UNCOMMON MAY-SEPT	
Blue Jay *	COMMON THR- BREED	

Name of Species	Locality	Date Seen
American Crow *	COMMON BREEDER	
Fish Crow *	UNCOMMON BREEDER	
Black-capped Chickadee *	COMMON BREEDER	
Boreal Chickadee		
Tufted Titmouse *	UNCOMMON BREEDER	
Red-breasted Nuthatch	UNCOMMON THR	
White-breasted Nuthatch *	UNCOMMON THR	
Brown Creeper	UNCOMMON WINTER	
Carolina Wren		
House Wren *	UNCOMMON MAY-SEPT	
Winter Wren		
Sedge Wren		
Marsh Wren		
Golden-crowned Kinglet	UNCOMMON WINTER	
Ruby-crowned Kinglet	MIGRANT	
Blue-gray Gnatcatcher	M	
Eastern Bluebird		
Veery		
Gray-cheeked Thrush		
Swainson's Thrush	M	
Hermit Thrush	M	
Wood Thrush	M	
American Robin *	COMMON BREEDER	
Gray Catbird *	COMMON BREEDER	
Northern Mockingbird *	COMMON BREEDER	
Brown Thrasher	M	
Water Pipit		
Cedar Waxwing *	UNCOMMON BREEDER	
Northern Shrike		
Loggerhead Shrike		
European Starling *	VERY COMMON BREEDER	
White-eyed Vireo		
Solitary Vireo	MIGRANT	
Yellow-throated Vireo		
Warbling Vireo *	FAIRLY COMMON BREEDER	
Philadelphia Vireo		
Red-eyed Vireo	MIGRANT	
Blue-winged Warbler		
Golden-winged Warbler		
Tennessee Warbler		
Orange-crowned Warbler		
Nashville Warbler	M	

Name of Species	Locality	Date Seen	Name of Species	Locality	Date Seen
Northern Parula	M		Chipping Sparrow *	UNCOMMON BREEDER	
Yellow Warbler *	COMMON BREEDER	MAY-AUG	Field Sparrow		
Chestnut-sided Warbler	M		Vesper Sparrow		
Magnolia Warbler	M		Lark Sparrow		
Cape May Warbler			Savannah Sparrow		
Black-throated Blue Warbler	M		Grasshopper Sparrow		
Yellow-rumped Warbler	M		Sharp-tailed Sparrow		
Black-throated Green Warbler	M		Seaside Sparrow		
Blackburnian Warbler	M		Fox Sparrow		
Pine Warbler			Song Sparrow *	COMMON BREEDER	
Prairie Warbler			Lincoln's Sparrow		
Palm Warbler			Swamp Sparrow		
Bay-breasted Warbler			White-throated Sparrow	UNCOMMON OCT-MAY	
Blackpoll Warbler	M		White-crowned Sparrow		
Black-and-white Warbler	M		Dark-eyed Junco	FAIRLY COMMON OCT-APR	
American Redstart	M		Lapland Longspur		
Worm-eating Warbler			Snow Bunting		
Ovenbird	M		Bobolink		
Northern Waterthrush	M		Red-winged Blackbird *	UNCOMMON BREEDER	
Louisiana Waterthrush			Eastern Meadowlark		
Connecticut Warbler			Rusty Blackbird		
Mourning Warbler			Common Grackle *	UNCOMMON BREEDER	
Common Yellowthroat *	UNCOMMON BREEDER		Brown-headed Cowbird	FAIRLY COMMON APR-SEPT	
Hooded Warbler			Orchard Oriole	M	
Wilson's Warbler	M		Northern Oriole *	UNCOMMON BREEDER	
Canada Warbler	M		Pine Grosbeak		
Yellow-breasted Chat			Purple Finch		
Scarlet Tanager	M		House Finch *	COMMON BREEDER	
Northern Cardinal *	COMMON BREEDER		Red Crossbill		
Rose-breasted Grosbeak			White-winged Crossbill		
Blue Grosbeak			Common Redpoll		
Indigo Bunting			Pine Siskin		
Dickcissel			American Goldfinch *	UNCOMMON BREEDER	
Rufous-sided Towhee	M		Evening Grosbeak		
American Tree Sparrow	UNCOMMON OCT-MAR		House Sparrow *	COMMON BREEDER	

* 35 species have been known to breed

M = MIGRANTS #s could be more based on more frequent observations

The sequence of species and name changes follow the major revision published in the Vol. 99 No. 3 July 1982

MASSACHUSETTS AUDUBON SOCIETY, LINCOLN, MASS. 01773

a checklist of MASSACHUSETTS BIRDS

Observed by Birds that could breed in Watertown, MA

Total Number of Birds Checked ______________ Year ________

Name of Species	Locality	Date Seen	Name of Species	Locality	Date Seen
Red-throated Loon			Green-winged Teal		
Common Loon			American Black Duck		
Pied-billed Grebe			Mallard	✓	
Horned Grebe			Northern Pintail		
Red-necked Grebe			Blue-winged Teal		
Northern Fulmar			Northern Shoveler		
Cory's Shearwater			Gadwall		
Greater Shearwater			Eurasian Wigeon		
Sooty Shearwater			American Wigeon		
Manx Shearwater			Canvasback		
Wilson's Storm-Petrel			Redhead		
Leach's Storm-Petrel			Ring-necked Duck		
Northern Gannet			Greater Scaup		
Great Cormorant			Lesser Scaup		
Double-crested Cormorant			Common Eider		
American Bittern			King Eider		
Least Bittern			Harlequin Duck		
Great Blue Heron			Oldsquaw		
Great Egret			Black Scoter		
Snowy Egret			Surf Scoter		
Little Blue Heron			White-winged Scoter		
Tricolored Heron			Common Goldeneye		
Cattle Egret			Barrow's Goldeneye		
Green-backed Heron			Bufflehead		
Black-crowned Night-Heron	✓		Hooded Merganser		
Yellow-crowned Night-Heron			Common Merganser		
Glossy Ibis			Red-breasted Merganser		
Mute Swan			Ruddy Duck		
Snow Goose			Turkey Vulture		
Brant			Osprey		
Canada Goose	✓		Bald Eagle		
Wood Duck	✓		Northern Harrier		

Name of Species	Locality	Date Seen	Name of Species	Locality	Date Seen
Sharp-shinned Hawk			White-rumped Sandpiper		
Cooper's Hawk			Baird's Sandpiper		
Northern Goshawk			Pectoral Sandpiper		
Red-shouldered Hawk			Purple Sandpiper		
Broad-winged Hawk			Dunlin		
Red-tailed Hawk	✓		Stilt Sandpiper		
Rough-legged Hawk			Buff-breasted Sandpiper		
Golden Eagle			Ruff		
American Kestrel	✓		Short-billed Dowitcher		
Merlin			Long-billed Dowitcher		
Peregrine Falcon			Common Snipe		
Ring-necked Pheasant			American Woodcock		
Ruffed Grouse			Wilson's Phalarope		
Wild Turkey			Red-necked Phalarope		
Northern Bobwhite			Red Phalarope		
Clapper Rail			Pomarine Jaeger		
King Rail			Parasitic Jaeger		
Virginia Rail			Laughing Gull		
Sora			Little Gull		
Common Moorhen			Common Black-headed Gull		
American Coot			Bonaparte's Gull		
Black-bellied Plover			Ring-billed Gull		
Lesser Golden-Plover			Herring Gull		
Semipalmated Plover			Iceland Gull		
Piping Plover			Lesser Black-backed Gull		
Killdeer	✓		Glaucous Gull		
American Oystercatcher			Great Black-backed Gull		
Greater Yellowlegs			Black-legged Kittiwake		
Lesser Yellowlegs			Caspian Tern		
Solitary Sandpiper			Royal Tern		
Willet			Roseate Tern		
Spotted Sandpiper			Common Tern		
Upland Sandpiper			Arctic Tern		
Whimbrel			Forster's Tern		
Hudsonian Godwit			Least Tern		
Marbled Godwit			Black Tern		
Ruddy Turnstone			Black Skimmer		
Red Knot			Dovekie		
Sanderling			Thick-billed Murre		
Semipalmated Sandpiper			Razorbill		
Western Sandpiper			Black Guillemot		
Least Sandpiper			Rock Dove	✓	

Name of Species	Locality	Date Seen	Name of Species	Locality	Date Seen
Mourning Dove	✓		Blue Jay	✓	
Black-billed Cuckoo			American Crow	✓	
Yellow-billed Cuckoo			Fish Crow		
Common Barn-Owl			Common Raven		
Eastern Screech-Owl	✓		Black-capped Chickadee	✓	
Great Horned Owl	✓		Boreal Chickadee		
Snowy Owl			Tufted Titmouse	✓	
Barred Owl	✓		Red-breasted Nuthatch		
Long-eared Owl			White-breasted Nuthatch	✓	
Short-eared Owl			Brown Creeper		
Northern Saw-whet Owl			Carolina Wren		
Common Nighthawk	✓		House Wren		
Chuck-will's-widow			Winter Wren		
Whip-poor-will			Sedge Wren		
Chimney Swift	✓		Marsh Wren		
Ruby-throated Hummingbird			Golden-crowned Kinglet		
Belted Kingfisher			Ruby-crowned Kinglet		
Red-headed Woodpecker			Blue-gray Gnatcatcher		
Red-bellied Woodpecker			Eastern Bluebird		
Yellow-bellied Sapsucker			Veery		
Downy Woodpecker	✓		Gray-cheeked Thrush		
Hairy Woodpecker	✓		Swainson's Thrush		
Northern Flicker	✓		Hermit Thrush		
Pileated Woodpecker			Wood Thrush		
Olive-sided Flycatcher			American Robin	✓	
Eastern Wood-Pewee	✓		Gray Catbird	✓	
Yellow-bellied Flycatcher			Northern Mockingbird	✓	
Acadian Flycatcher			Brown Thrasher		
Alder Flycatcher			Water Pipit		
Willow Flycatcher			Cedar Waxwing		
Least Flycatcher			Northern Shrike		
Eastern Phoebe	✓		Loggerhead Shrike		
Great Crested Flycatcher			European Starling	✓	
Western Kingbird			White-eyed Vireo		
Eastern Kingbird	✓		Solitary Vireo		
Horned Lark			Yellow-throated Vireo		
Purple Martin			Warbling Vireo		
Tree Swallow	✓		Philadelphia Vireo		
N. Rough-winged Swallow			Red-eyed Vireo		
Bank Swallow			Blue-winged Warbler		
Cliff Swallow			Golden-winged Warbler		
Barn Swallow			Tennessee Warbler		

Name of Species	Locality	Date Seen	Name of Species	Locality	Date Seen
Orange-crowned Warbler			American Tree Sparrow		
Nashville Warbler			Chipping Sparrow		
Northern Parula			Field Sparrow		
Yellow Warbler	✓		Vesper Sparrow		
Chestnut-sided Warbler			Lark Sparrow		
Magnolia Warbler			Savannah Sparrow		
Cape May Warbler			Grasshopper Sparrow		
Black-throated Blue Warbler			Sharp-tailed Sparrow		
Yellow-rumped Warbler	✓		Seaside Sparrow		
Black-throated Green Warbler			Fox Sparrow		
Blackburnian Warbler			Song Sparrow	✓	
Pine Warbler			Lincoln's Sparrow		
Prairie Warbler			Swamp Sparrow		
Palm Warbler			White-throated Sparrow		
Bay-breasted Warbler			White-crowned Sparrow		
Blackpoll Warbler			Dark-eyed Junco		
Black-and-white Warbler			Lapland Longspur		
American Redstart			Snow Bunting		
Worm-eating Warbler			Bobolink		
Ovenbird			Red-winged Blackbird	✓	
Northern Waterthrush			Eastern Meadowlark		
Louisiana Waterthrush			Rusty Blackbird		
Connecticut Warbler			Common Grackle	✓	
Mourning Warbler			Brown-headed Cowbird	✓	
Common Yellowthroat	✓		Orchard Oriole		
Hooded Warbler			Northern Oriole	✓	
Wilson's Warbler			Pine Grosbeak		
Canada Warbler			Purple Finch		
Yellow-breasted Chat			House Finch	✓	
Scarlet Tanager			Red Crossbill		
Northern Cardinal	✓		White-winged Crossbill		
Rose-breasted Grosbeak			Common Redpoll		
Blue Grosbeak			Pine Siskin		
Indigo Bunting			American Goldfinch	✓	
Dickcissel			Evening Grosbeak		
Rufous-sided Towhee			House Sparrow	✓	

The name changes and sequence of species follow the A.O.U. Checklist of North American Birds, 6th edition, 1983.

revised 12/86